The Appendage Exposed

Getting In Touch With Your Appendage

By Scott Stites

The primal instinct to build and operate a ribbon controller has been a consistent component of the human psyche since the dawn of man. Cave drawings and the fossilized remnants of early ribbon devices indicate that Neanderthal Man indeed had mastered the ribbon controller several thousand years ago. Harnessing the natural power of lightning, these devices likely used an array of ferret-like creatures as the sound generating device. The resistive element of the first ribbon controller has long since disintegrated, leaving the actual material subject to speculation. The prevailing theory holds that it was almost certainly charcoal, either from a campfire or from the remains of the previous operator.

It wasn't until the twentieth century that ribbon controllers became practical as a non-lethal musical instrument. One of the most ubiquitous devices of the last half of the twentieth century was developed by Dr. Robert Moog. This controller was made famous (perhaps infamous) through its use by the progressive rock musician Keith Emerson. Emerson was known to drive home a particular musical point by shooting flames from the end of his controller, perhaps in homage to the unsung Neanderthal musicians of yore.

A ribbon controller can be used for a number of purposes. The dominant conception is that a ribbon controller is used for controlling pitch. As a pitch controller, without quantization, the ribbon controller ranks at rather difficult, a notch or two below the extremely difficult rating of the theremin. However, when mastered as a pitch controller, it is a sublimely expressive instrument.

The ribbon controller can handle other tasks as well – for example, rather than being the sole source of pitch control, a ribbon controller can be used to modulate the pitch signal generated by another device, such as a keyboard or a sequencer. In this application, the ribbon controller excels at applying very expressive vibrato and slides from note to note.

The signals produced by a ribbon controller can be used to control other less pitch-related events. Filtration, amplitude, note timbre and modulation can all be controlled quite dynamically with a ribbon controller. If the ribbon controller is so equipped, it may also be used to generate gate and trigger signals within a larger musical system.

So, now that we know what a ribbon controller is good for, what, pray tell, *is* a ribbon controller?

Quite simply, a ribbon controller is a long resistive element that, when pressed at any point, comes into contact with a conductive element, thus creating a path of variable resistance from either end of the resistive element to the conductive element, allowing applied voltage or current to generate signals that will, in turn, influence voltage controlled musical devices.

Huh?

OK, a ribbon controller is just a long, drawn out potentiometer with some extra junk added. If you think of a slider potentiometer, you're pretty close to the idea. But, instead of moving the slider to change the resistive value, you press on the ribbon at various points with some object, such as (but not limited to) a finger.

The Mechanics of a Voltage Divider Based Ribbon Controller

A "normal" potentiometer consists primarily of two elements: a strip of resistance that possesses a constant resistance along its length and a "tap" that is used to provide contact at any point along the resistive strip. From one end of the strip of resistance to the other, the value is always fixed. For example, from one end of a 1000 Ohm pot to the other, it will always read 1000 Ohms. As mentioned, there is a third connection to the pot besides these two "outside" points - this connection is the "tap". The tap is always in contact with the resistive strip, and is the element that moves when you turn a knob on a rotary pot or slide the slider on a slide pot.

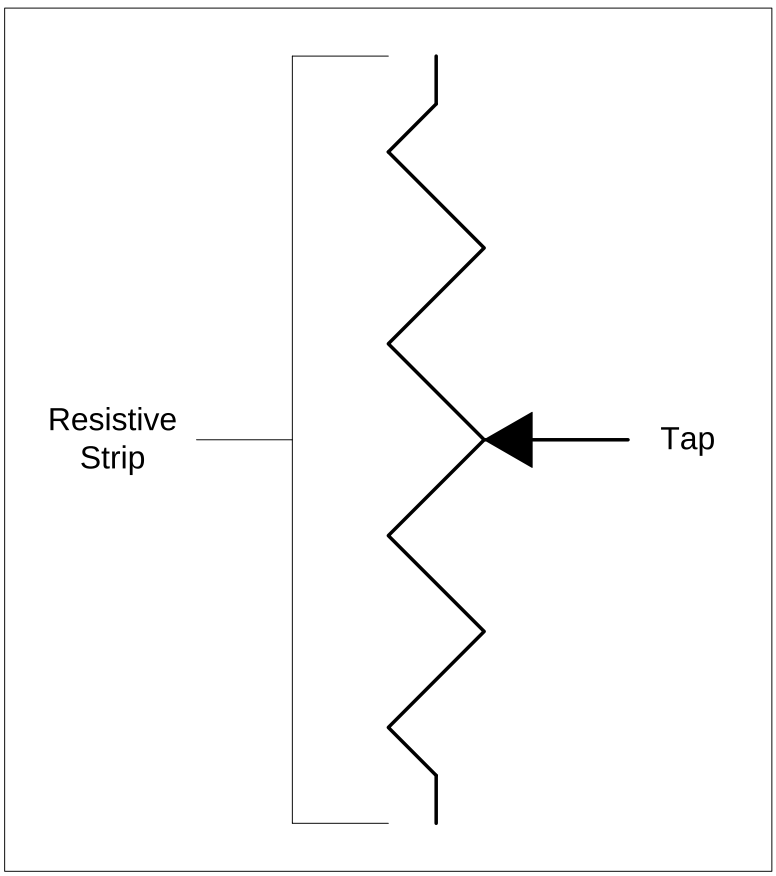


Figure 1: The Potentiometer or "Pot"

Let's say the tap is in the dead center position. Therefore the tap is contacting the resistive strip right in the middle. If the resistive strip is linear (IE, it's a linear pot), then from one end of the resistive strip to the tap, it is 500 Ohms, and from the other end of the resistive strip to the tap, it is 500 Ohms. If you move the knob or slider so that it is only a quarter of the way up, then from one end of the resistive strip to the tap it is 750 Ohms, and from the other end of the resistive strip to the tap it is 250 Ohms. Thus, the resistance from either end of the strip to the tap is completely variable with a potentiometer, which is why, I guess, it's *called* a potentiometer.

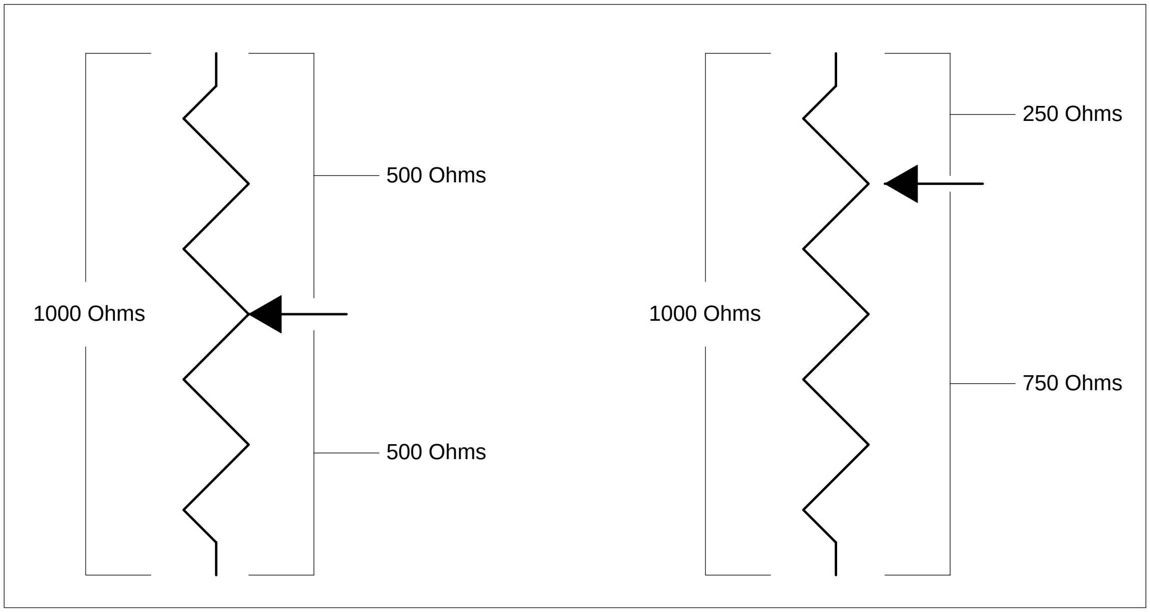


Figure 2: Moving the Tap Changes Its Contact Point Along the Resistive Strip

If voltage is placed on one end of the resistive strip, and the other end of the resistive strip is left unconnected, then the *current* at the tap varies with the position of the tap – this is because the resistance between the end of the strip to which the voltage is connected and the tap varies with the position of the tap. The pot is simply following Ohms Law, which states that voltage is equal to current times resistance. Actually, Ohm's law is just like a bad preacher – it repeats itself three times in slightly different ways, yet is always saying the same damn thing:

$$\mathbf{I = V/R}$$

or…

$$\mathbf{V = I*R}$$

or……

$$\mathbf{R = V/I}$$

If you know this, you know electricity, but don't start re-wiring your house yet…..there's something called the Watt that may get in your way.

For those of you new to electronics, "I" means Inductance (which is a fancy term used instead of current).   Inductance is expressed in Amperes, or "Amps" for short, and because it sounds cool. "V" is, of course, for Voltage, which is expressed, coincidentally, in Volts. Voltage is very useful for reanimating dead corpses, or assemblages of dead body parts sewn into one conglomerate being, among other things. "R" stands for

Resistance, which is expressed in "Ohms", because that's the name of the feller that invented resistance. You will often see "Ohms" represented by the Omega symbol (Ω) as its secret, special code.

As you can see, these three properties are locked in a death ménage-a-trois – jacking with one always affects at least one of the others, because that's the way Mother Nature likes it. And that's the way ribbon controllers and pots like it, too.

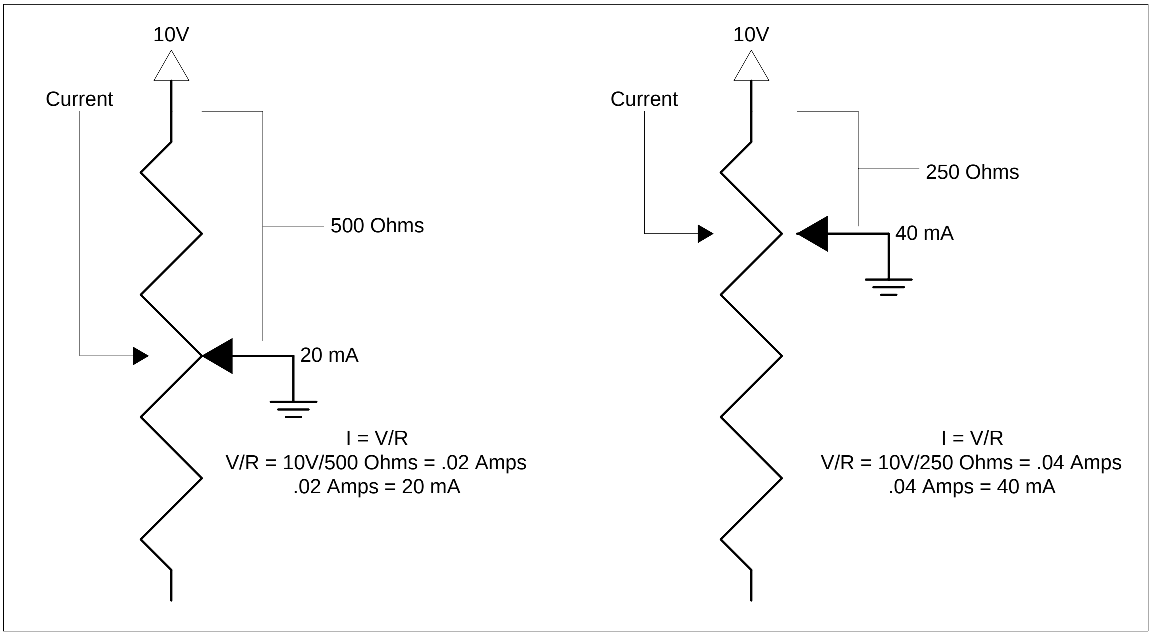


Figure 3: The Rheostat – a Pot Configured to Control Current

Figure 3 shows what happens when one end of a pot is wired to a voltage source and the tap is wired to ground. The three horizontal lines at the end of the tap represent ground (another secret, exclusive electro-symbol). Current flows from the voltage source to ground. Well, an engineer will tell you the opposite is true – the engineer will tell you that the current actually flows from ground to the voltage source, but most people with a life look at it the way all electronic symbols seem to indicate, so don't worry about that. Anyway, when a pot is configured to control current, it's often called a "rheostat".

On the left side of Figure 3, the tap is situated in the middle – so the current flows through half of the strip (which, in this example, is one half of 1,000 Ohms, which is 500 Ohms). Ohms law tells us that 20 mA (.02 Amps) will flow through the 500 Ohms on its way to ground.

On the right side, the tap has been moved so that only a quarter of the resistive strip is passing the current. That means 10V is flowing through 250 Ohms, which gives you a current of 40 mA. Now, guess what happens if you move the tap so that the current is flowing through 10 Ohms – that will give you 1 Amp, which is one hell of a lot of juice; enough juice to easily cause burns, sparks, and general mayhem. This may be a clue that using this document as your sole research in re-wiring a house may not be such a good idea.

Now, actually, the Appendage is not really configured as a rheostat, but rather is configured as a voltage divider, which is another job a pot handles with extraordinary ease. A voltage divider uses Ohms law to present a signal better expressed as voltage rather than a current at the tap output.

Remember that V=I*R, right? Well, that means if you shove I through R, that makes V. This is the coolest part of Ohms law there is, in my humble opinion. Let's say you connect 10V on one end of the resistive strip, and connect ground on the other end, ignoring the tap for the time being. 10V/1000 Ohms = 10 mA. So, you get 10 mA flowing through your 1000 Ohm strip. Ground is 0V, so that means your resistive strip has *dropped* 10 V across it (this is a very important principle, don't forget it. Ever.). In other words, one end of the strip is 10V and the other end is 0V.

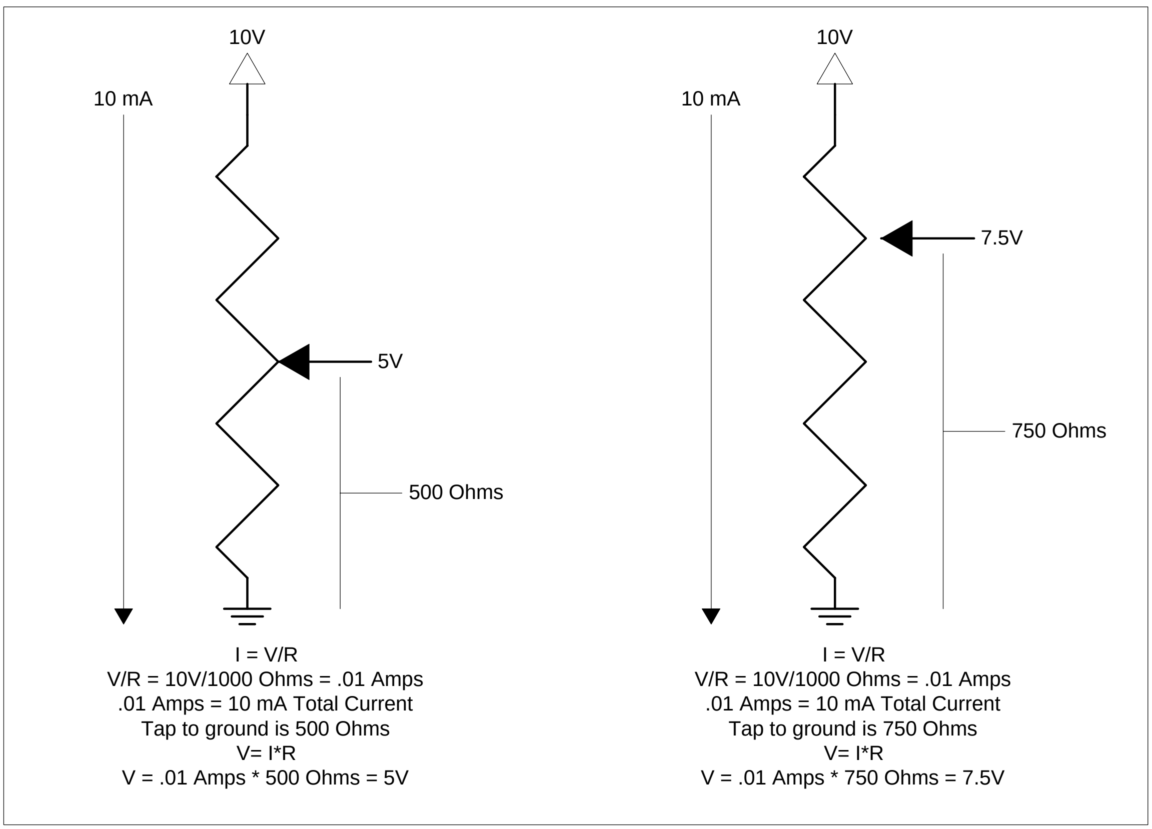


Figure 4: The Variable Voltage Divider – a Pot Configured to Control Voltage

If you place the tap right at the middle of the strip, that's like chopping your strip into two separate resistors. The top resistor is 500 Ohms and the bottom resistor is 500 Ohms. Each of those two resistors is passing 10 mA to ground. Remember, we drop 10V across the 1000 Ohm strip. Well – because the two resistors are equal in value, each one is dropping 5V so that 10V is the total drop. The top resistor drops 5V, but let's pretend we don't know that. We'll just act like lunkheads and solve for the unknown value which is voltage (wink, wink):

I*R = V
.01 Amps * 500 Ohms = 5 Volts

Ah! So we know the top resistor is dropping 5V. Well, it started out at 10V, so we subtract the 5V from 10V, so we know that the tap will be right at the 5V mark. An easier way to do it is to determine the voltage drop of the bottom resistor. This will tell you immediately what the voltage is at the top of this resistor, without having to subtract it from the starting voltage. But, we just figured the voltage here, so lets move on.

Let's move the tap of the pot to one quarter of the way down from the top of the resistive strip. Now the two resistors formed by tapping the strip at this point are unequal. One resistor will have to drop more voltage than the other in order to get to 0V at ground. The largest resistor will drop the most voltage. The top resistor is now 250 Ohms, and the bottom resistor is now 750 Ohms. Let's do it the easy way and figure the voltage drop of the bottom resistor:

I*R = V
.01 Amps * 750 Ohms = 7.5 Volts

So, we have 7.5 Volts at the tap. Congratulations, you're well on your way to having the privilege of getting in touch with your Appendage. The ribbon of the Appendage is just a pot, and the tap is where you press your finger. Voltage is applied to one end, and ground is applied to the other, just like in Figure 4. Don't worry – you won't get "zapped" by pressing the ribbon because (A) it's insulated – the electrons can't jump out and kill you and (B) the voltage is so low, you wouldn't know it if you did touch it. You'd be dead instantly. No, just kidding, it's such a low potential and is supplied by so little current, it couldn't be felt.

When the ribbon is pressed, the voltage at that point is present on the tap, and, if that tap is connected to a voltage controlled object, such as a VCO, the pitch of the VCO will change to whatever value the voltage at the tap tells it to change to. If you slide your finger up the strip, the VCO goes up in pitch. If you slide your finger down the strip, the VCO goes down in pitch. Beautiful, innit?

But, there's a catch: A ribbon controller differs slightly from a "normal" potentiometer in that its tap is not in constant contact with the resistive strip. The tap only comes into contact with the resistive strip when the ribbon is pressed. That means, as soon as you release pressure, the voltage seen by your VCO will go to some other value. Which means "press, I get note, not press, I get crap", which is basically true. The VCO will only hold the pitch for as long as *you* press the ribbon. You better figure out some way to mute that VCO when you release, or find some way to make the voltage either stay put or go to a known value until you do something else with the ribbon.

The easiest thing to do is to put a large value resistor from the tap to ground. This way, at least the VCO will always go to some known pitch – the pitch that corresponds to 0V. So, now you release your ribbon and your VCO always drops back to the same pitch. It's an improvement, but not much of one. It does provide a certain playing style that depends on that known 0V pitch of the VCO, but it ultimately is still a limiting factor.

The tap voltage could be used to generate a gate signal that could be used to gate a Voltage Controlled Amplifier (VCA) that the VCO signal is passing through. Then, the VCO will only sound on the tap voltage notes. Some designs use an additional pressure sensor or a capacitive sensor to detect when the ribbon is pressed to generate this gate signal. But, ultimately, the gate must shut off immediately after the ribbon is released, or the base pitch of the VCO will be heard on each note.

The best solution in the analog world is some sort of device that could sample the tap voltage when the ribbon was pressed, and hold that voltage when the ribbon was released; some device like, oh, I don't know, a Sample and Hold.

That's exactly what Dr. Moog did with his ribbon controller. When the ribbon was pressed, its output fluidly changed voltage with position of the pressure (IE, sliding the finger up and down the controller) and held the last value the tap voltage was at when the finger was lifted up. And, that's exactly what the Appendage does as well, though through a different method, with two sample and holds instead of one. It is from these two sample and hold devices that the Appendage derives most of its voltage outputs.

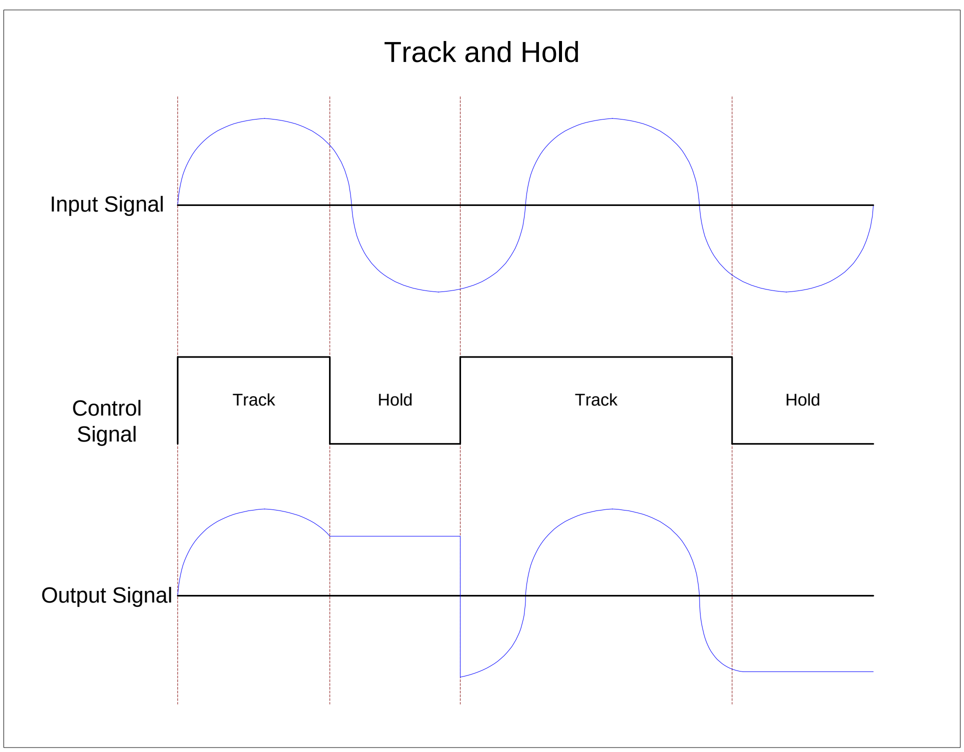


Figure 5: Track and Hold

Technically speaking, the Moog ribbon controller used a "Track and Hold". The difference is this: the output of a track and hold will track, or "follow", the voltage at the input until it is told to "hold", whereupon the voltage currently at its input is "frozen" on its output until it is told to track again. A sample and hold will only take a sample or a "snapshot" of the input voltage each time it is told to do so, and will hold this "snapshot" on its output until the next sample is taken.

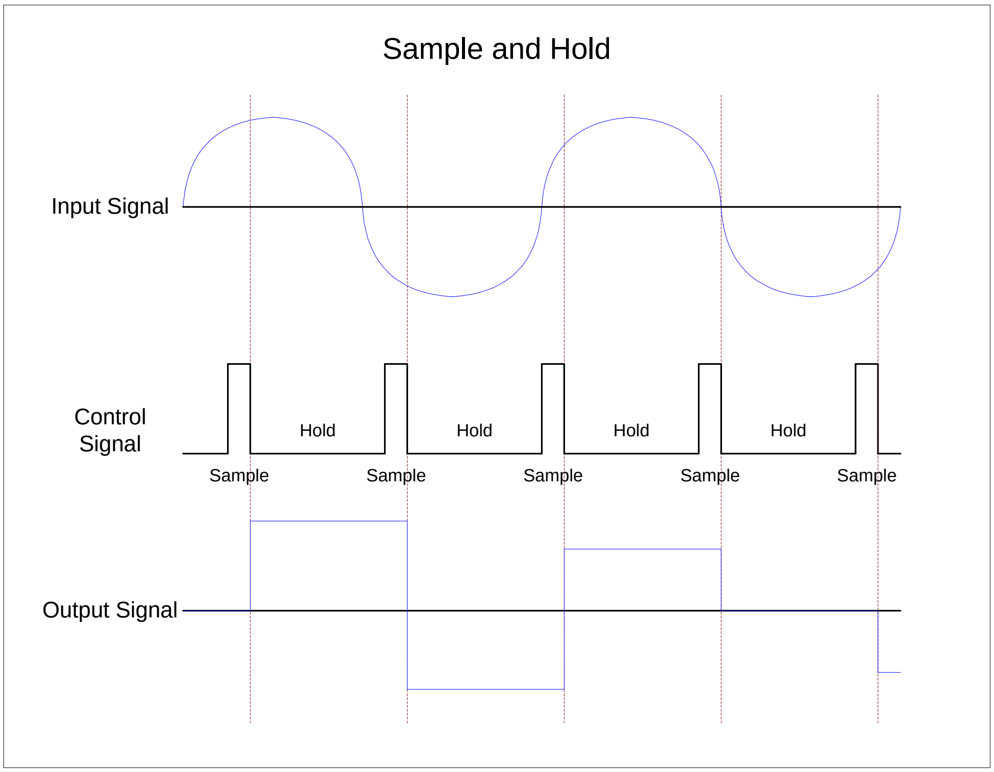


Figure 6: Sample and Hold

The Appendage uses a rapidly clocked sample and hold to duplicate the track and hold aspect needed for sliding voltages while still holding the voltage upon release of the ribbon. This is implemented because of the way the Appendage extracts its gate and trigger signals, and for other reasons to be explained shortly.

In any event, the track and hold and sample and hold circuits form a sort of analog "memory" – when told to do so by the control signal, they hold or "remember" the tap voltage at that instant in time. They share that remembered voltage with the outside world while the tap voltage does whatever it does when the pressure on the ribbon is released. So, now, when the finger is lifted off the ribbon, the ribbon controller output remains at the last voltage the finger accessed before it was lifted – anything that is controlled by that voltage will hold at that point as well. The VCO maintains its pitch, the VCA its amplitude, the filter its cutoff, and so on and so forth.

Holding the voltage is a solution, but there has to be something to tell the hold circuit when to hold and when to allow the signal to freely flow through it.

Analog hold circuits use capacitors to store a charge. Dr. Moog's elegant solution was to feed a capacitor the signal while the ribbon was pressed. This capacitor was on the gate input of a field effect transistor (FET) which allowed the signal to change freely as long as the ribbon was pressed, and then hold the charge on the cap when the ribbon was released.

Another method is to use some sort of pressure sensor that senses the pressure and "tells" the hold circuit to hold when it senses a release of pressure.

The Appendage uses both a track and hold and a sample and hold (again for reasons we'll get to here in a moment), so a different solution was used. The method used by the Appendage employs a comparator circuit to "look" at the tap voltage.

A comparator is a specialized circuit that looks at a voltage and compares it with another voltage, which is often a fixed reference. The output of the comparator will always be in one of two states: high or low. A comparator can be wired so that when the voltage on one input is below its reference level, its output will be high. If the input voltage is above its reference level, its output will be low. Of course, a comparator could also put out a low signal when the voltage feeding it is lower than its reference, and put out a high signal when the voltage feeding it was above the reference level – it all depends on how it's wired.

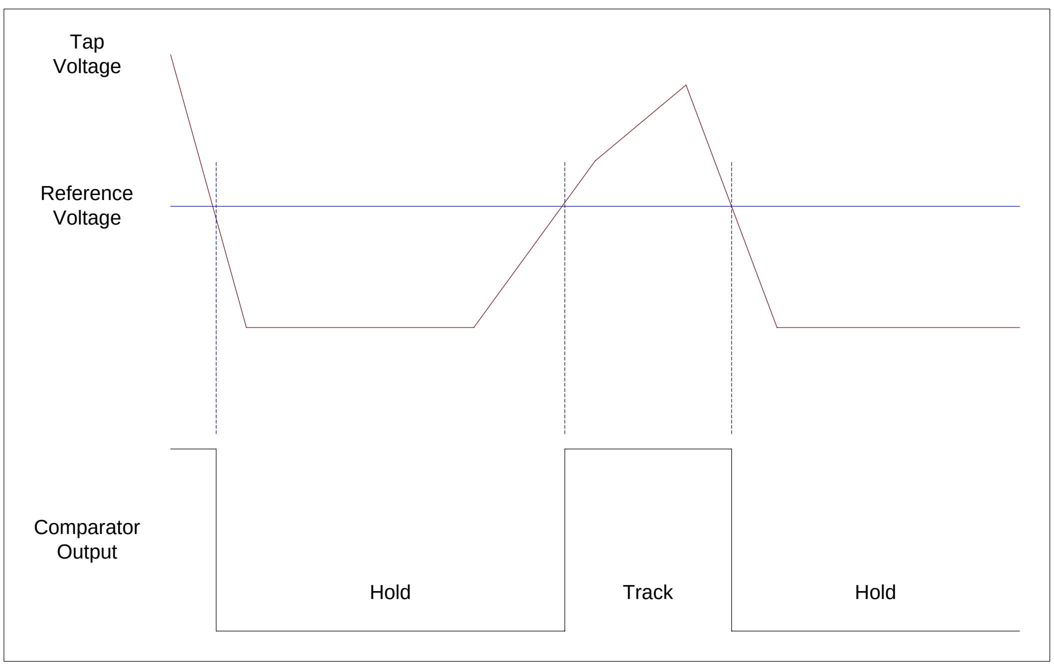


Figure 7: A Comparator Signal Used to Control Track and Hold

Comparators are extremely fast, so when the voltage feeding it passes the reference level, its output trips from one state to the other very, very quickly. As such, it's sort of the electronic version of a finger flipping a wall switch. Therefore, using this method, when the tap voltage falls below a specific level, the comparator "knows" that the pressure has been released, and instructs the hold circuits to hold.

Of course, if one thinks about the method used by the Appendage, an obvious problem immediately surfaces: if the tap voltage has to drop in order for the hold circuit to hold the last value, wouldn't that defeat the purpose? In other words, the voltage has to have dropped, so it can't be holding the last value, right?

Obviously this would be a problem without employing some additional circuitry. John Simonton's solution on his ribbon controller design was to apply a slight bit of "lag" to the tap voltage feeding the track and hold. A "lag" circuit slows down the rate of change of voltage. For example, if you flip off a light switch, the voltage feeding the light bulb drops nearly instantaneously and the light goes dark instantly. If you place a lag circuit between the switch and the light bulb, the sudden drop in voltage caused by flipping the switch is slowed down. Now, the light bulb, instead of immediately switching off, will slowly dim down to the off state – the drop in voltage is slowed down by the lag circuit.

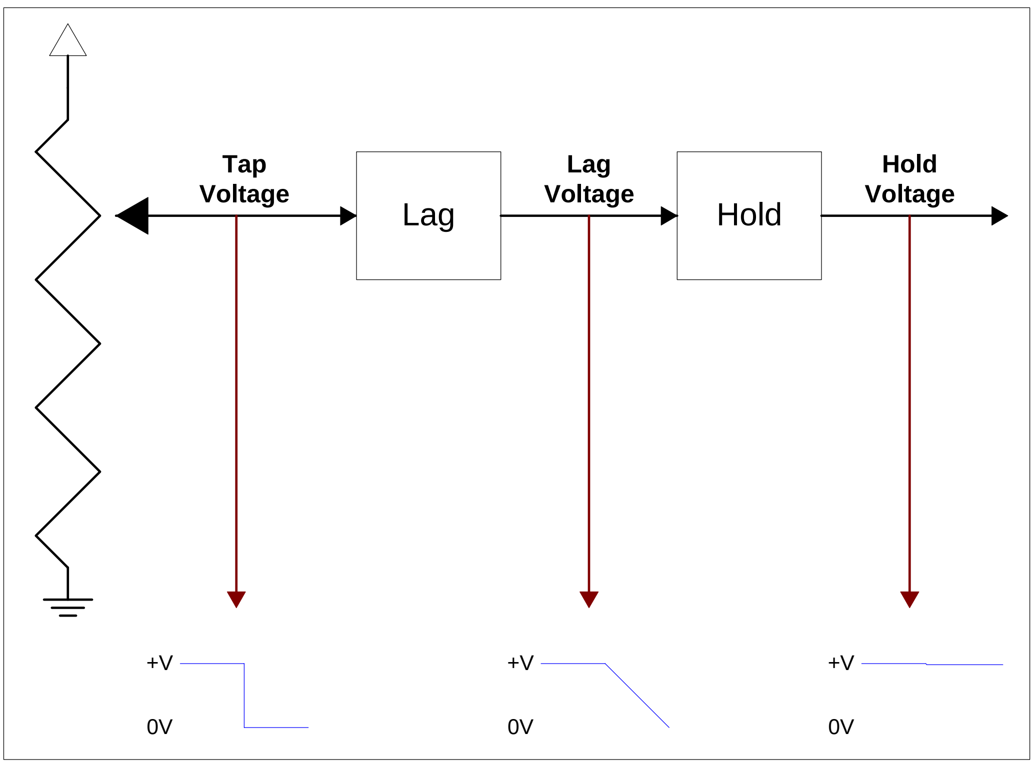


Figure 8: Using a Lag Circuit to Slow the Tap Voltage for Holding

So, by the same token, when the pressure is released on the ribbon, the voltage going through the lag is going to drop relatively slowly. This lagged voltage feeds the hold circuit. As this version of the tap voltage slowly drops, the "real" tap voltage drops nearly instantly, "trips" the comparator, and instructs the sample and hold to hold the lagged voltage before it has had a chance to drop significantly and detune whatever the tap voltage is controlling.

As a design goal, the Appendage is intended to be able to do groovy things with more than one point of pressure. In other words, if one places one finger on the ribbon, then places a second finger to the right or to the left of the first finger, the tap voltage is expected to change to a new value instantly. A lag will slow the voltage down at the tap to cause a slight bit of "glide" between these two voltages. The voltage will lag just a little bit when going down in voltage, and, by the same measure, it will lag just a little bit when going up in voltage. This is perceived as a sort of slide up or down in voltage, rather than a discrete step in voltage. A glide function can be desirable at times, but not all the time, no matter how slight. It is for this reason, and other functional reasons, the Appendage does not employ a lag circuit to hold the voltage in a certain range when pressure is released.

Instead, the Appendage uses an entirely different method. The voltage at the tap is fed to a third rapidly clocked sample and hold circuit, called the "guard" sample and hold. The voltages at the input and output of this sample and hold are constantly monitored. If the voltage at the input of the guard differs from the voltage at the output of the guard, beyond a certain amount, the guard circuit tells the sample and hold circuits responsible for holding the voltage to hold off on looking at the voltage on the output of the guard sample and hold. If the voltages on the input and output of the guard sample and hold agree again while the pressure comparator signal still indicates pressure is applied, the signal sample and hold circuits resume their business. If the guard sample and hold input and output voltages never again agree before the pressure comparator goes low, then the signal sample and hold circuits never reflect that change in voltage. Thus, the tap output never has a chance to drop at all, and it is not lagged in the slightest. This method serves not only to prevent a lag on the output, but also discriminates against any "bounce" noise on the ribbon.

Every physical switch has a certain amount of "bounce". In other words, when you flip that light switch, it actually never *instantly* goes "off" or "on" – the contacts of the switch literally bounce against each other for a tiny amount of time. This results in a very short period of time (usually thousandths of a second) in which the voltage "bounces" up and down rapidly. This is not noticeable on a human scale, but a sample and hold can just as easily "sample" a bounce voltage as it can the actual voltage it's intended to sample. In this respect, the ribbon is no different than the switch – the tap will "bounce" a bit before the voltage settles down. The guard system used by the Appendage is designed to discriminate between a "bounce" signal, and a valid, intended voltage. It does this by timing how long a signal is stable before it is allowed to be sampled and tracked. This happens over such a short interval, the function is transparent to the operator of the Appendage.

Now that we've ascertained how to hold a control voltage generated by the ribbon, we should consider one other type of signal necessary to complete the basic controller: the gate signal.

Producing a gate signal allows the ribbon controller to form discrete notes rather than one long, continuous note. The gate signal is generally used to either gate a VCA directly, or to control an envelope generator, which can then be used to not only control the VCA, but also a VCF or any other voltage controlled device.

Ideally, the gate would activate whenever the ribbon is pressed, and return to its opposite state when the ribbon is released. As opposed to the tap voltage, the gate signal is reasonably easy to acquire at the exact right time.

Dr. Moog actually used a touch plate that was separate from the ribbon itself to generate the gate signal. This required touching the plate while one also touched the ribbon in order to articulate notes when using an envelope generator and/or a VCA.

Other methods include (again) either a separate pressure sensor, or a comparator fed by the tap voltage, both of which are essentially the same setups used to initiate track and hold operations. The Appendage uses a comparator fed by the tap voltage to generate not only a gate signal, but also a short trigger pulse signal. This comparator is referred to as the "pressure comparator" and provides the signal from which the gate signal is generated, and also when to signal the sample and hold circuits to begin sampling.

The gate signal of the Appendage stays high as long as pressure is applied to the ribbon. The Appendage also generates a trigger signal, which is a short, transitory pulse that is useful in controlling a number of devices ranging from envelope generators to drum voice modules. In its basic mode, the trigger pulses high for 5 milliseconds at the start of each gate signal (in other words, each time the ribbon is pressed). More advanced modes of re-triggering during a "held" note will be discussed later.

Ribbons and Pots: The Rest of the Story

Now that this document has thoroughly driven home the point that a ribbon is simply a potentiometer in a long, drawn out ribbony form, it's time to more thoroughly point out why a ribbon is not exactly like your standard rotary or slider pot. Knowing the difference is essential in moving on to the less-arid portion of this document. One difference has been mentioned in passing, but will now get a bit more attention.

The first major difference between a ribbon and a normal pot is that the tap of the ribbon is only in contact with the resistive strip while pressure is applied. With a normal potentiometer, the tap always has a path to either end of the resistive strip. So, the current of the tap always has a path to ground or whatever signal is applied to at least one end of its resistive strip.

But, with a ribbon, the tap is totally isolated when pressure is not applied. This presents a situation that a "normal" potentiometer will never experience, and that is a tap that is unconnected to a signal source or ground. If the tap is not connected to something when pressure is not applied, what voltage does it go to? It doesn't go to zero volts (which, hint, hint, is what we want here) because it's not connected to ground, and it doesn't go to the value of the voltage applied, because it's not connected there, either. Instead, it floats. And one does not want the tap voltage floating off in never-never land between notes – it must go to some known value. And, with the Appendage, that value is 0V, which is the voltage of the ground signal.

The solution is to provide a resistive path between the conductive strip (the tap) of the ribbon and ground – a pull-down resistor. Now, this value cannot be too low, because when pressure is applied, the pull-down resistor is going to clamor for its share of the current, and this will skew the voltage at the tap. It can't be too high, because the conductive strip wants to see a fairly clear path to ground when no pressure is applied. Fortunately, there's a middle ground there that works quite well – not too low, and not too high, but juuussst right….

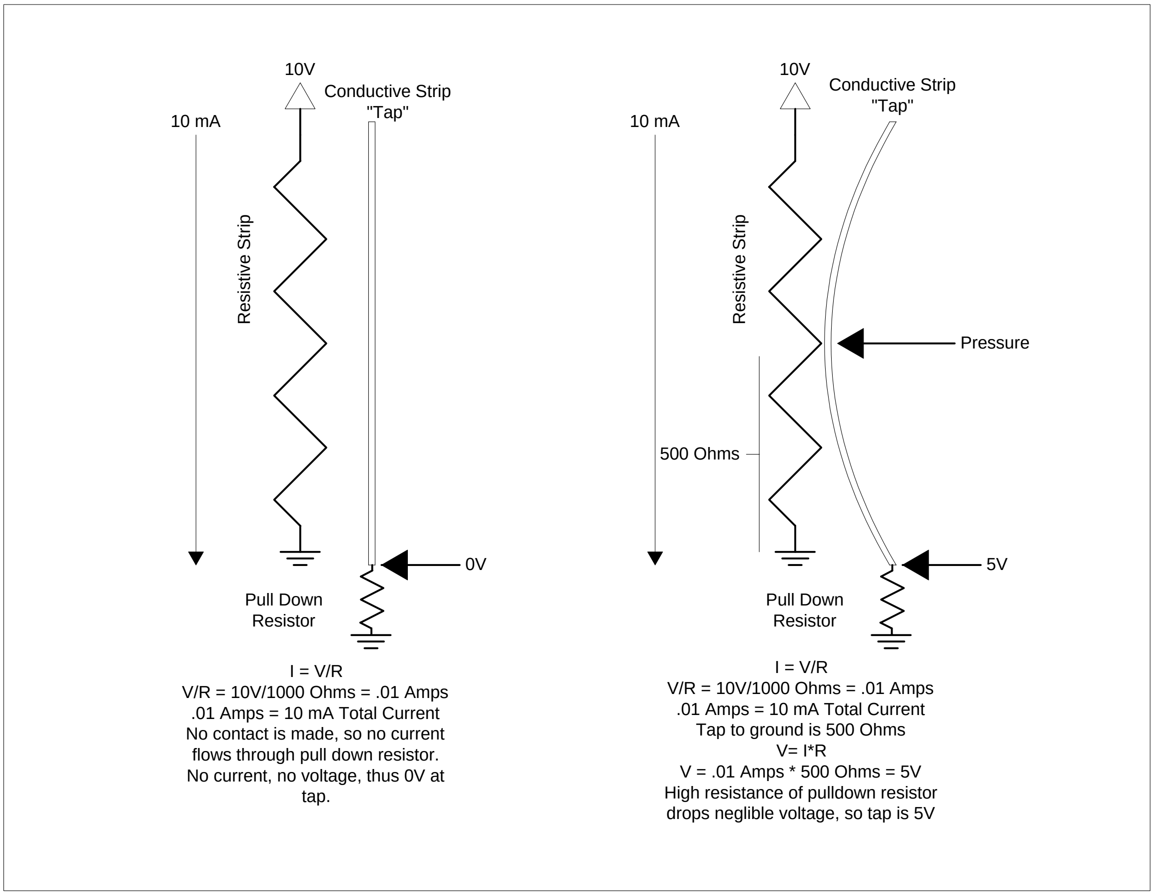


Figure 9: The Ribbon and the Pull-Down Resistor

Figure 9 illustrates how the ribbon works, and the role the pull-down resistor plays. On the left hand side of Figure 9 is a schematic diagram of the ribbon while no pressure is applied. You see the resistive strip and the conductive strip, which acts as the tap. As long as no pressure is applied, the conductive strip does not touch the resistive strip, so there is no source for current to flow through the conductive strip. The pull-down resistor, however, provides a path to ground, which is 0V, so the voltage at the tap is 0V when no pressure is applied.

On the right-hand side of Figure 9, pressure is applied at the very center of the ribbon. The conductive strip is coming in contact with the resistive strip, so the current at the center of the resistive strip flows through the conductive strip. A portion of the current will also flow through the pull-down resistor, but the pull-down is at a high enough value as to make any voltage drop it presents is so small as to be irrelevant. Therefore, the voltage generated by the current at the point of contact with the conductive strip stays essentially the same: 5V. Thus, when no pressure is applied to the ribbon, the tap is at 0V, and when pressure is applied, the voltage at the tap jumps to the value present at the point of contact with the resistive strip.

Multiple Pressure Points

Now that the main difference between a "normal" potentiometer and a ribbon has been explained, the other major difference can be explored more easily. The second difference is the tap of a ribbon can contact the conductive strip in more than one place.

It was mentioned before in this diatribe that the Appendage was designed to do "groovy things" when more than one pressure point is applied to the ribbon. In actuality, any ribbon controller can do "groovy things" when more than one pressure point is applied. This section is not about the Appendage-centric groovy things, but is more about the groovy things any ribbon will do when you lay more than one finger (or other object) on the ribbon.

When using only one pressure point, things are pretty much cut-and-dried: you place one finger on the "low" end of the ribbon, and the controller puts out a low voltage. You move that single pressure point up towards the high end, and the output voltage rises up linearly in proportion to where your finger is at any point.

Now, if you place one finger on the lower end of the ribbon, and one finger on the higher end, *the output voltage moves to some value that really doesn't seem to correspond to the position of either pressure point.*

In other words, if your left finger is pressing the position that corresponds with two volts, and the right finger is pressing the position that corresponds to eight volts, the output voltage will be at some value between those voltages. Don't worry about that - it's just Ohms Law messing with your head.

Why does this happen? It's because you've just performed a maneuver most potentiometers aren't designed to perform – you've basically created two taps that bypass a section of the resistive strip – you're letting the current make an end run around the resistive strip, so the current doesn't feel the need to drop the voltage that this ignored patch of resistance would have dropped.

In order to illustrate the effect, let's look at our resistive element as divided up into three parts. For this illustration, let's use 10,000 Ohms (10k) as our resistive strip and 10 volts as our voltage source. The current passing through the strip is therefore 1 milliamp (1 mA), which is one thousandth of an amp.

10V/10000 = .001 A or 1 mA

We'll begin with one pressure point, which is one tap, to see what we get. Let's place it towards the bottom of the strip, right at the 2k Ohm point. That single point will provide 2V on the tap, because 1 mA of current is passing through that last 2k Ohm of resistance to ground:

.001 A * 2000 Ohms = 2V

Now let's place our single pressure point at the 8k Ohm point – now we have 8V on the tap.

.001 A * 8000 Ohms = 8V

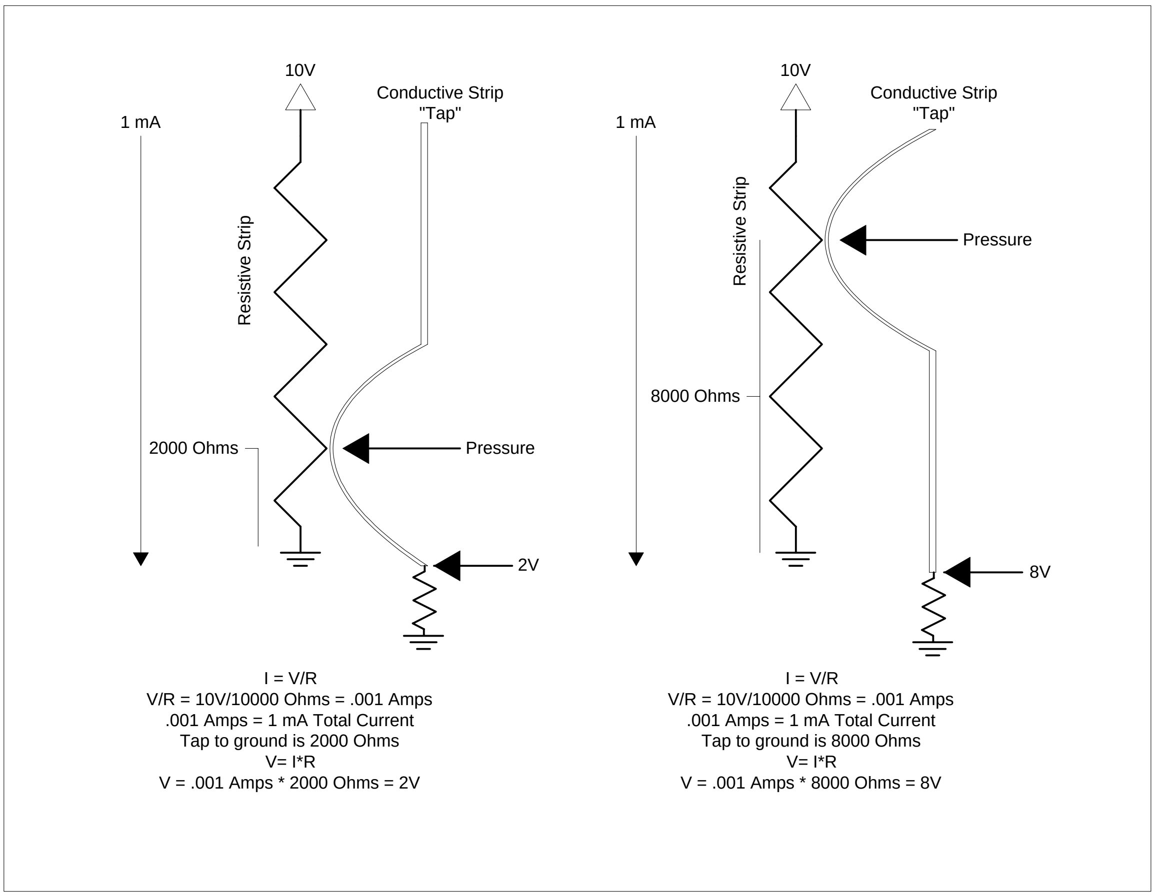


Figure 10: The Ribbon and Different Points of Single Pressure

Now, let's press both of those points simultaneously. Now the current passes through the first 2k Ohm of the ribbon as expected, but then it meets our pressure point, which is applying a conductive strip at the 8k Ohm point. The current sees this conductive point and says “Screw that resistance to ground, this conductive strip is the path of least resistance” and passes on through the conductive strip. It sails along the conductive strip to the point that is in contact with the 2k Ohm point, and has no other way to go to ground, but through that last 2k Ohm to ground. Grumpily, it does just that, dropping its remaining voltage along the way.

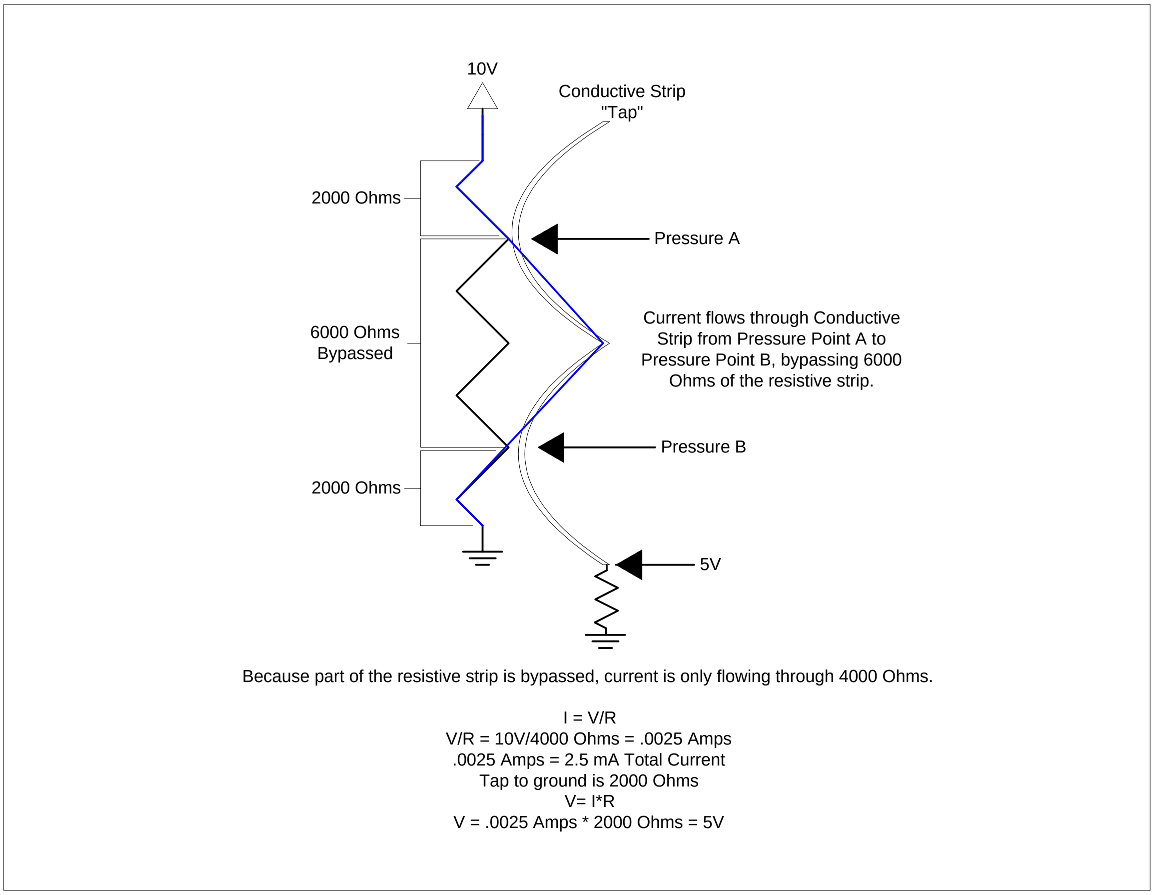


Figure 11: The Ribbon and Two Simultaneous Points of Pressure

So, that “free ride” the current got through the conductive strip, which is serving as the tap, bypasses the point between 8k Ohms and 2k Ohms on the resistive strip. That means that 6k Ohms of the resistive strip no longer “exists” as far as our strict authoritarian Ohms Law sees it. In other words, Ohms Law now only sees a 4k Ohm resistive strip rather than the original 10k Ohm resistive strip – the original 10k Ohms minus the “missing” 6k Ohms. Ohms Law says voltage divided by resistance is current, so now you have altered how much current is flowing through the strip. This changes the ground game! Now, instead of 1 mA flowing through the ribbon, we have 2.5 mA flowing through the ribbon:

10V / 4000 Ohms = .0025A (2.5 mA)

So, now, from the lower pressure point, the remaining 2k Ohms of resistance is dropping not 2V, but 5V!

2000 Ohms * .0025 A = 5V

So, you don't get the original 2V or the 8V of either pressure point, but some value in between. It's not a terribly linear relationship, but is still musically useful. There is a method that can be employed to force Ohms Law into "playing nice" and render more intuitive results, but that comes later. For now, suffice it to say, placing a finger at the 8V position while another is at the 2V position will not result in the output voltage rising to 8V, but rather will go to some value in between, in this case 5V.

So, the question may have popped into the reader's head, why use two points of pressure in the first place? There are two reasons. Two points of pressure allow one to "hammer-on" and "hammer-off" notes by holding one pressure point and applying pressure to and withdrawing pressure from a second pressure point; applying a point of pressure and hammering on "above" that point will bend the voltage up, and hammering on below the first point of pressure will bend the voltage down. The second reason is that it is possible to derive an additional signal from the ribbon by applying the second pressure point. In other words, now, in addition to the voltage presented at the tap as a result of the voltage division created by applying pressure to the ribbon, a second voltage can be developed that is *proportional to the length of ribbon between two pressure points*. This voltage is a result of the property of current, which, as seen, always prefers the path of least resistance.

Extracting TFS Voltage Using a Ribbon Configured as a Voltage Divider

First of all, one may wonder what "TFS" means. This signal is the voltage that is relative to the length of ribbon between two pressure points. That's a mouthful, and a short, catchy term was hard to dream up, so, instead, the term "Two Fingered Salute" came to mind, and rather stuck. Thus, "TFS" means "Two Fingered Salute", IE, a situation where at least two fingers are poking at the ribbon.

The TFS voltage is developed by taking advantage of the fact that the total resistance of the ribbon changes when more than one pressure point is applied. As noted in the previous section, and Figure 11, the amount of current flowing through the entire ribbon assembly will increase when two points of pressure bypass a section of the resistive strip. The regulated voltage applied to the top of the resistive strip will never (or shouldn't!) change and the voltage at the bottom of the strip will always remain at 0V (ground), so obviously something has to be added to the equation in order to get this voltage. That something is an additional resistor, which develops a voltage drop across it proportional to how much current is flowing through it – there's Ohms Law again!

This resistor is placed between the bottom of the resistive strip and ground. In actuality, this resistor serves two purposes: generating the TFS voltage and providing an offset to the tap voltage so that it will always rise well above 0V, regardless of the position of the pressure point, in order to excite the pressure comparator that is constantly monitoring the tap voltage. But, for now, we'll concentrate on TFS.

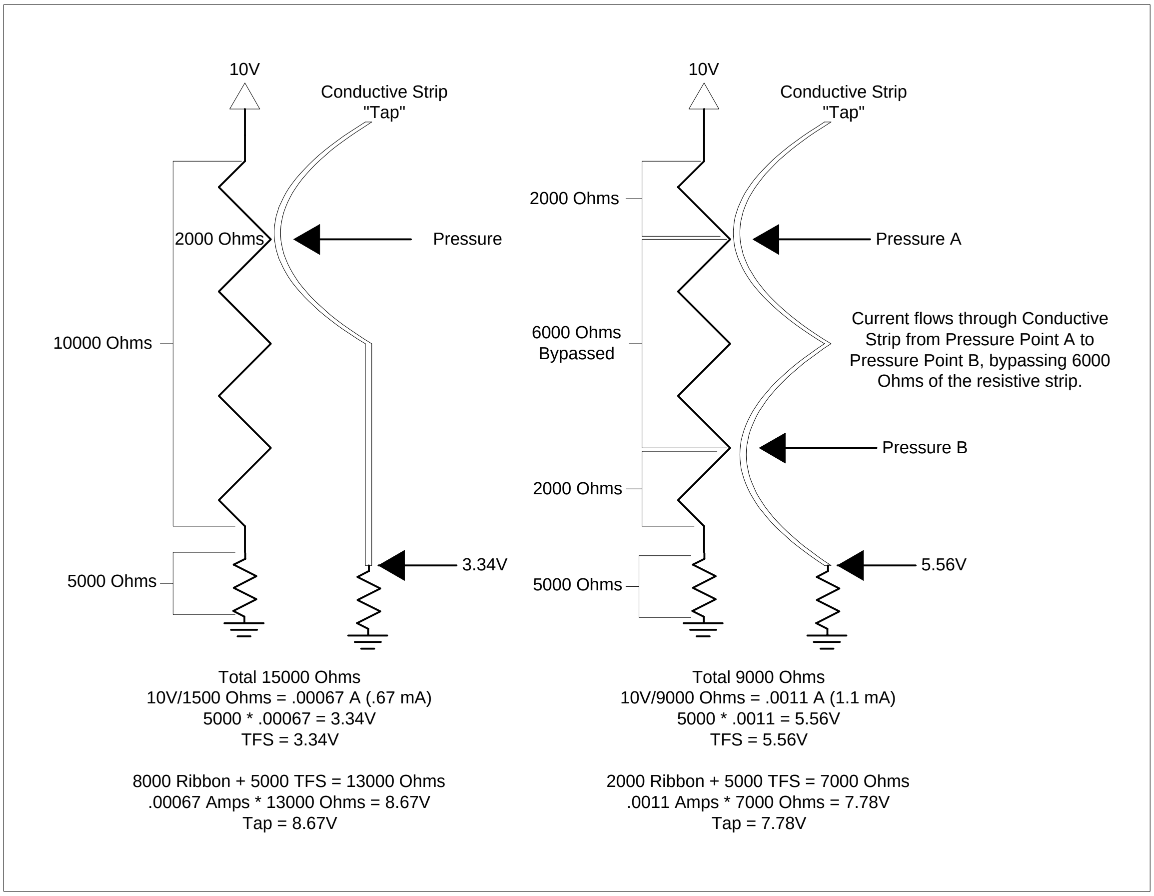


Figure 12: The TFS Function

Refer to Figure 12: Let's assume our new TFS resistor is 5000 Ohms (5k Ohms). This resistor is in series with the resistive element of the ribbon, which is 10k Ohms, so the total resistance is 15000 Ohms (15k Ohms). With 10V applied to the top of this resistance, the total current is .00067 A (0.67 mA).

10V / 15000 Ohms = .00067 A

So, the "resting voltage" (the voltage with no pressure applied) of the TFS signal is 3.34V.

.00067 A * 5000 Ohms = 3.34V

On the right side of Figure 12, pressure is applied 2k Ohms from the top of the resistive strip, so 8k Ohms remains below the pressure point. In addition to that 8k Ohms, the TFS resistor is providing another 5k Ohms, so a total of 13k Ohms is in series to ground from the pressure point. So, the voltage at the tap is now 8.67V:

.00067 A * 13000 Ohms = 8.67V

Note that this pressure point is in the same position as the upper pressure point in Figure 10. In Figure 10, that point was 8V, but now that the TFS resistor is in place, that point has shifted up to 8.67V.

On the left illustration in Figure 12, though a single pressure point is applied, the TFS voltage is still at its resting voltage of 3.34V – it hasn't changed. That is because only one point of pressure is applied – none of the resistive strip is bypassed – so the total resistance of the strip and the TFS resistor remains the same.

On the right hand side of Figure 12, two pressure points are applied, bypassing 6k Ohms of the resistive strip (just as in Figure 11). The total resistance of the resistive strip plus the TFS resistor has now changed to 11k Ohms. Because the resistance has changed, the amount of current passing through the strip and the resistor has changed as well – it has increased from 0.67 mA to 1.1 mA.

10V / 11,000 Ohms = .0011 A (1.1 mA)

And because the amount of current passing through the TFS resistor has increased, the voltage drop across it has increased as well:

.0011 A * 5000 Ohms = 5.56V

Applying the second point of pressure increased the TFS voltage from 3.34V to 5.56V, an increase of 2.2V. Therefore, we have provided a new signal by applying two points of pressure. The further apart the two points of pressure are, the higher the TFS voltage will be; the closer together the two points of pressure are, the lower the TFS voltage will be.

The Appendage offsets and scales the TFS voltage: at rest, the TFS voltage is at 0V. At maximum spread (one point of pressure at the very bottom of the ribbon and a point of pressure at the very top of the ribbon) will produce a TFS voltage of 10V. It does not matter where the points of pressure are on the ribbon, the only thing that matters is that there are two points of pressure. Placing a point of pressure at the middle and one at the top of the ribbon will result in the same voltage as placing a point of pressure in the middle and another one at the bottom of the ribbon. TFS, therefore, is independent of position on the ribbon.

The "resting" voltage of the raw TFS signal in this example is 3.34V. Note now, that if pressure is applied at the very bottom of the resistive strip, so that there is no resistance between the resistive strip and the TFS resistor, the tap voltage will now also be 3.34V – it no longer goes to 0V, which is a good thing. This ensures that a voltage adequate to excite the pressure comparator will always be on the tap when pressure is applied. If the

TFS resistor were not there, a 0V signal at the very "bottom" of the resistive strip would be difficult to detect.

The TFS voltage is proportional to the distance between two pressure points, but it is not linear – the response as the distance is widened is more of a logarithmic curve – it gets from 0 to 10V (after offsetting and scaling) but the line from 0 to 10V is a curve, not a straight shot. This is due to Ohms law – graphing it out is beyond the scope of this document. Fortunately, this has a very "natural" feel to it.

As discussed before, the tap voltage of dual pressure points also is not linear – pressing a pressure point, then moving up the length of ribbon, that, using a single point of pressure, would provide four volts does not generate four volts – again, it will be some voltage in between the two points. This also feels natural, for want of a better expression. Only a single point of pressure will provide a linear, proportional voltage as the pressure is applied to various parts of the ribbon.

Obviously, when TFS is used, via two pressure points, the tap voltage will change as well – two pressure points changes the tap voltage and the TFS voltage.

All of the above applies to this mode of operation, which is called the "Voltage Mode". What? There's another mode?

Yes, there is another control mode, called the "Current Mode". It uses electronics to subvert Ohms Law to achieve its own agenda…..

Current Mode Operation

Of course, a natural law, such as Ohms Law, really cannot be circumvented – if that were true, all of our vehicles would run on perpetual motion flywheels and Exxon would be in the pinwheel industry instead of draining all the dino-juice out of this planet.

But, there are ways to manipulate the laws into accomplishing a goal, and one way to manipulate Ohms Law (at least in regards to ribbon controllers and keyboards) is to feed a fixed current into the equation using a constant current source.

A constant current source can be thought of perhaps as a water hose that squirts a constant amount of water out, no matter the size of container it's feeding. In other words, it's a current source that generates a fixed amount of current into a resistive path, like the resistive strip of the ribbon. As harped about before in this document, when feeding the ribbon with a voltage, changing the total resistance of the ribbon changes the amount of current flowing through it. But – if the ribbon is fed by a constant current source, then changing the resistance of the ribbon doesn't faze the current one bit – it stays the same or… huh…constant. So, something else has to give. And that something else is the tap voltage and the TFS voltage. They change in strange and wonderful ways. Well, let's just say they act differently in a few not insignificant ways…

The first difference is how the controller reacts with two points of pressure when the ribbon is fed from a constant current source. When feeding the ribbon with a voltage, hammering-on above the initial point of pressure and hammering on below the initial point of pressure both produce a change in the tap voltage. But, when the ribbon is fed with a constant current source, *hammering-on above the initial point of pressure produces no change in the tap voltage.* In other words, as far as hammer-ons are concerned, the ribbon now has left note priority. You can hammer-on below (to the left of) the initial point of pressure and produce a change in voltage, but you cannot hammer-on a note above (to the right of) the initial point of pressure and produce a change in tap voltage.

The second difference is that the hammer-ons, which are now left note priority, are linear to position. Unlike the voltage mode, if you press a point that is two volts below the initial point with a single pressure point, the tap voltage will drop two volts, not some middle value between the two points of pressure.

The third difference is that TFS is linearly proportional to the distance between two pressure points, unlike the voltage mode of operation, which has more of a logarithmic curve to the TFS response.

And, finally, the fourth difference is that the TFS voltage can be manipulated without changing the tap voltage. In other words, if you place a pressure point on the ribbon and then place a second pressure point above (to the right) of the pressure point, the tap voltage does not change, but the TFS voltage increases. This allows, for example, control of the pitch of an oscillator with the tap voltage, while controlling some other parameter independent of the pitch with a second point of pressure.

So take *that*, Ohms Law.

Now, you may ask "Why does a constant current source make such a difference?" Well, you came to the right document. Ohms Law states that voltage is equal to the amount of current times the amount of resistance. When feeding the ribbon with a voltage, the voltage at the top of the ribbon is a constant. Resistance is a variable (because you can change it by applying pressure) and current is a variable, because we aren't controlling it like some manic dictator – therefore, if the resistance changes, and the voltage at the top of the ribbon is constant, then the current must change in order to satisfy Ohm's twisted demands.

But, now, all we've done is elect to have, instead of a constant voltage at the top of the ribbon, a constant current instead. Ohm's law states current is equal to voltage divided by resistance. Well, our current is constant, so if our resistance changes, now our voltage is forced to change, too. And it so works out that it does it in a linear fashion.

A single point of pressure produces the same results between current and voltage mode, so let's first take a look at the effect two points of pressure has on the tap voltage. Refer to Figure 13. You'll note that the voltage source at the top of the resistive strip has been replaced with a box and what looks like a truncated Olympics Flag. Actually, those two rings represent a current source. In this example, the constant current source is putting out .0005 A (0.5 mA) of current. It does this rain or shine; lots of resistance or scant resistance. It just doesn't care. It's there to put out 0.5 mA and, by God, that's what it's going to do.

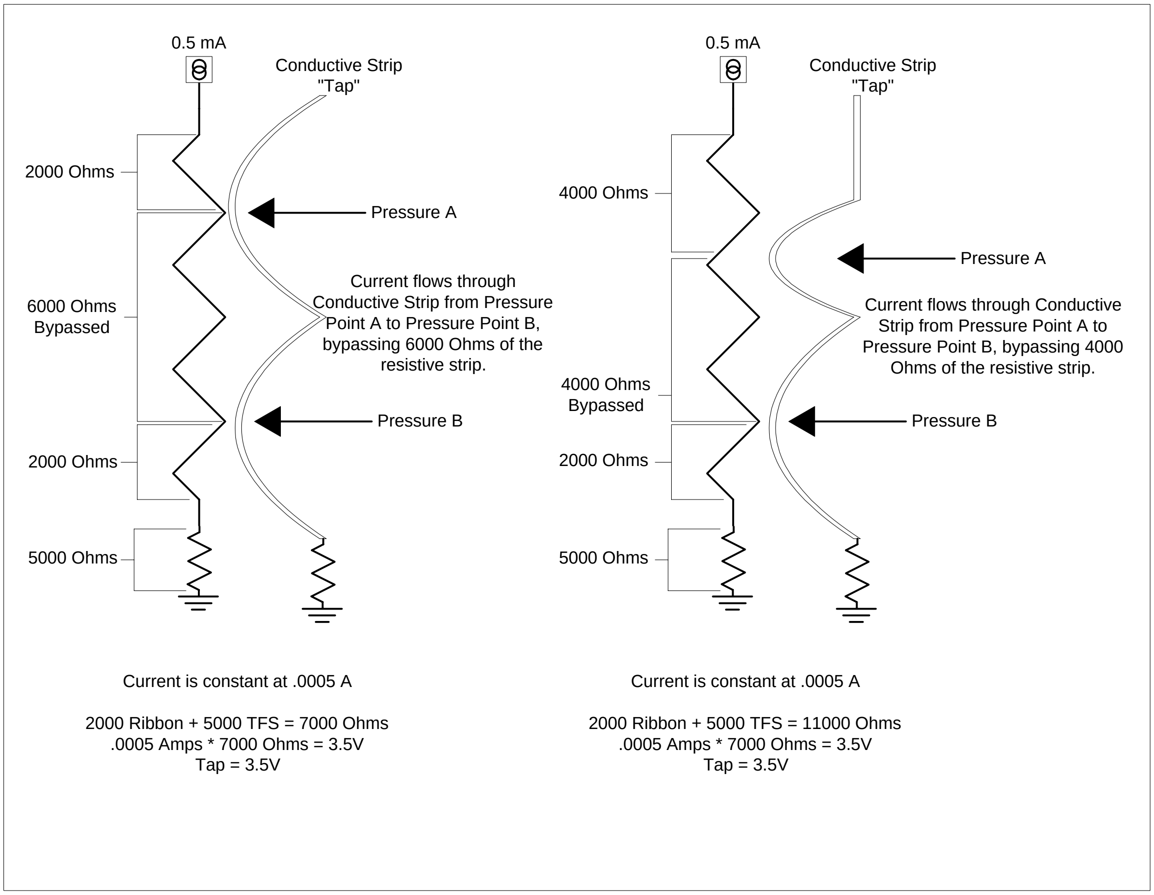


Figure 13: Dual Pressure Points in Current Mod of Operation

On the left hand side of Figure 13, we have our by-now-familiar example of two pressure points, with one pressure point being 2k Ohms below the top of the resistive strip, and the second pressure point being 8k Ohms below the top of the resistive strip (2k Ohms from the very bottom of the strip). Our TFS resistor is still there, because it is a fixture of the Appendage. The two pressure points bypass 6k Ohms of the resistive strip, so the current must pass through the top 2k Ohms of the strip, the bottom 2k Ohms of the strip, and the 5k Ohms of the TFS resistor on its way to ground. And, know what? The constant current source doesn't give a hoot. It doesn't care. Even with that reduced resistance it still puts out (all together now) 0.5 mA.

So, all *we* care about is that last 2k Ohms of the resistive strip and the 5k Ohms of the TFS resistor, which comes to 7k Ohms altogether. That 7k Ohms has 0.5 mA running through it, so it is forced to drop 3.5V:

.0005 A * 7000 Ohms = 3.5V

So, our tap voltage is 3.5V. On the right hand side of Figure 13, the upper pressure point has moved to the position 4k Ohms below the top of the resistive strip. Now only 4k Ohms are bypassed. So the total resistance has changed. When voltage was feeding the ribbon, that was a big deal, wasn't it? Ha! Not so with the constant current source. It doesn't give a hairy rat's derriere about it. It's still going to put out 0.5 mA. And – look – we never moved the lower pressure point; it's still 2k Ohms above the bottom of the resistive strip, and the added 5k Ohms of the TFS resistor puts that at 7k Ohms to ground. Do I really need to write out the equation again? OK:

.0005 A * 7000 Ohms = 3.5V

That's right, though we moved our second point of pressure and changed the total resistance, our tap voltage did not budge. That's your right hand priority speaking there. Now, if you look at it in this way, you'll see there's more significance than meets the eye: Say you didn't press those two points at the same time. Say you pressed the top one first, then hammered on the lower one. On the left side of the illustration, you hammered on from one voltage down to the 3.5V position. You didn't get some value in between the top and the bottom points of pressure, you got 3.5V. Now, on the right side of Figure 13, you are hammering down from a different position to the 3.5V position. You again get 3.5V at the tap, instead of some value in between. Thus, your left hand hammer-on's are linear with the position of the hammer-on. Releasing the lower point (hammer-off) of course returns the tap voltage back to the "top" voltage.

So, the only thing that matters in current mode of operation as far as tap voltage is concerned is, "Which point is the lowest?" The voltage of the lowest point of pressure is the de-facto value produced at the tap of the ribbon; any point of pressure above that point is ignored.

Though the tap voltage value doesn't change between the two examples, something else does: the TFS voltage. This illustrates the fact that one can change the TFS voltage without changing the tap voltage. So, if one slid the top pressure point from the example on the left side of Figure 13 to the position in the example on the right side of Figure 13, the TFS voltage would have dropped a linear, proportional amount. Say one was controlling the pitch of a VCO with the tap voltage and was also using the TFS voltage to control the amplitude of a sine wave LFO that was modulating the VCO: the pitch of the VCO would have remained constant, but the level of vibrato would have quickly or gradually diminished, depending on how long one took to slide from one position to the other.

The TFS voltage in the constant current mode is actually taken from a different point in the circuit than the TFS voltage derived from the voltage mode. The current mode TFS voltage is taken from the top of the resistive strip – the resistive strip is acting as the TFS resistor.

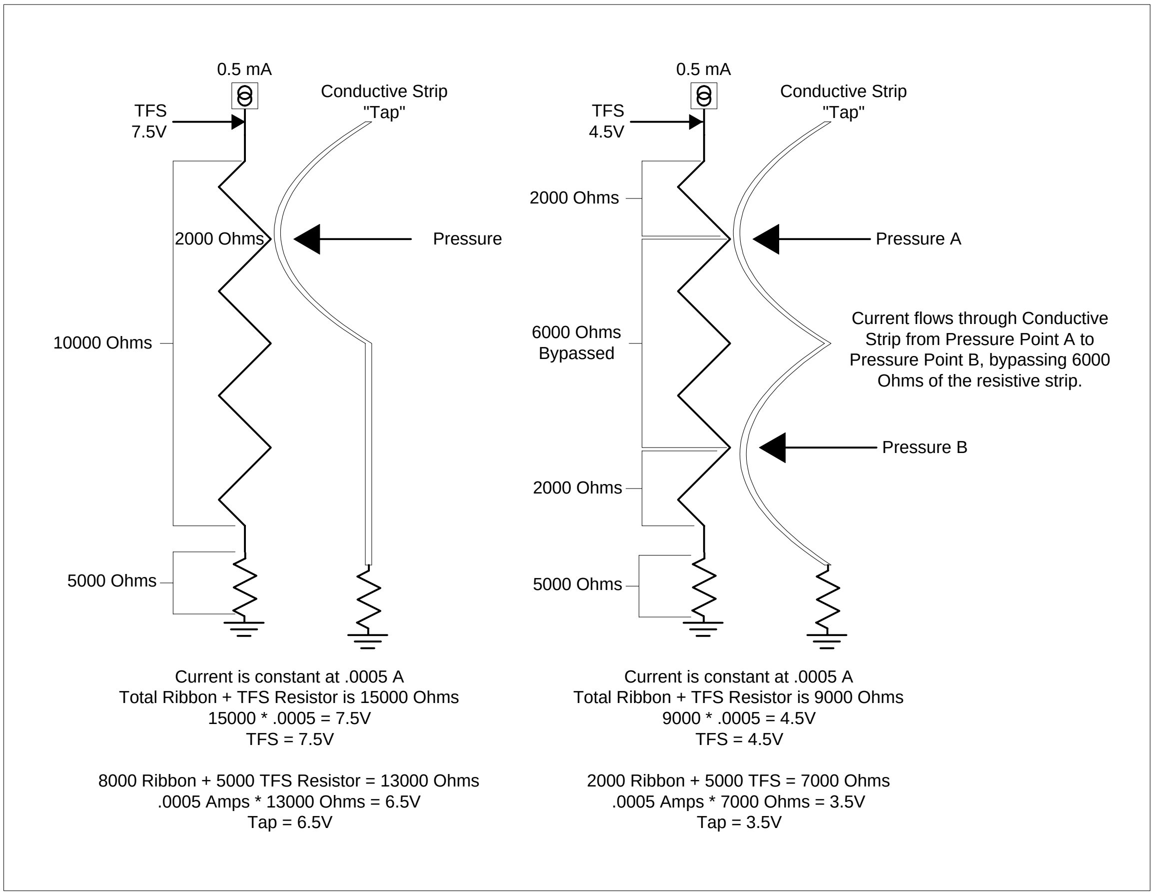


Figure 14: TFS Function in Current Mod of Operation

On the left hand side of Figure is a depiction of the ribbon, fed with a constant current source, with only one point of pressure applied. The total resistance through the ribbon and the voltage TFS resistor is 15,000 Ohms (15k Ohms). Essentially, with a constant current source, all voltages are derived by inducing a voltage across a resistance by forcing the constant current through them. So, at the top of the resistive strip, the resistance to ground is 15,000 Ohms, thus the voltage at that point is 7.5V:

.0005 A * 15000 Ohms = 7.5V

7.5V is the "resting voltage" of the raw current mode TFS signal. This means, with no pressure point, or only one pressure point, this voltage remains at 7.5V. On the right side of Figure 14, we have an illustration depicting two pressure points with the same setup. The two pressure points are bypassing 6k Ohms, so there is 4k Ohms of the ribbon plus 5k Ohms of the voltage TFS resistor remaining between the top of the resistive strip and ground – a total of 9k Ohms. So, in this example, the TFS voltage is now 4.5V:

.0005 Amps * 9000 Ohms = 4.5V

Like the voltage mode, the current mode TFS changes proportionally to the amount of ribbon between two pressure points. Unlike the Voltage Mode TFS, the current mode TFS changes linearly, and there is one other distinction: the current mode TFS drops lower and lower the further the two pressure points are from each other. If you recall, the voltage TFS increased the further the two points were apart.

The Appendage circuit addresses this issue to make the TFS function compatible between modes: it inverts, offsets, and scales the current TFS voltage so that it is, at a single pressure point, at 0V, and with the furthest dual pressure spread (a pressure point at the very bottom of the ribbon and a pressure point at the very top of the ribbon), it produces a maximum of 10V.

The Voltage Mode and Current Mode of operation each have their special properties. The Voltage Mode of operation has a more intuitive, natural feel to it, while the Current Mode of operation has a linear dual pressure point mode of operation and allows changes in TFS without altering the tap voltage, but at the cost of limiting the operation (in its native mode) to left hand priority.

The author feels that both modes are indispensable, and thus they are both a part of the Appendage Touch Ribbon Controller.

As a further aside, it is possible to produce a right hand priority of sorts to the current mode of operation. The TFS voltage is linear, and the Appendage allows mixture of control voltages. Mixing in the TFS voltage in the right proportion provides a linear, right hand hammer-on, slide capability to the current mode of operation. The mix function will be described later on in this document.

Initial, Slide and Bend Voltages

Now that the hot ribbon action has been more thoroughly explained, and that whole thing with the TFS has been approached, we can now concentrate a bit more on what happens to the tap voltage once pressure has been applied.

The TFS voltage is the only control voltage generated by the Appendage that isn't held in "memory". In other words, once the second pressure point is released, the TFS voltage will return to 0V. However, as mentioned before, the tap voltage is held in memory so that when pressure is released, the output voltage stays at the last value it was at until pressure is applied again.

As alluded to before, there are actually two "memories" which the Appendage uses to generate three different output voltages. In addition to that, there is a third "short term" memory that is used for internal operation.

Of course, these "memories" are really sample and hold circuits. In actuality, the Appendage uses five different sample and hold circuits. Two pairs of these five sample and hold circuits are paired together to form two very high performance S&H circuits.

By pairing and synchronizing two sample and hold circuits in this manner, the output of the combined circuit exhibits an outstandingly low droop rate.

Every sample and hold circuit exhibits droop. In other words, while a sample and hold circuit is “holding” the voltage, the held voltage will begin to creep down as time passes. If one is controlling a VCO with a held voltage, and the droop rate is an excessively high droop rate, the VCO can be heard descending in pitch as the voltage droops. The dual circuit approach used in the Appendage has an extremely low droop rate – it is around 2.5 mV (.0025 V) per minute. In other words, one would have to wait around a good long time before any detuning of the oscillator could be audibly detected.

The “third” short term sample and hold circuit does not take this precaution, however, it is only “looked at” in 1 mS (.001 second) time intervals, so even if droop were incredibly excessive, it wouldn’t have the time to go anywhere before the next sample was taken.

This “short term” memory is called the Guard Sample and Hold.

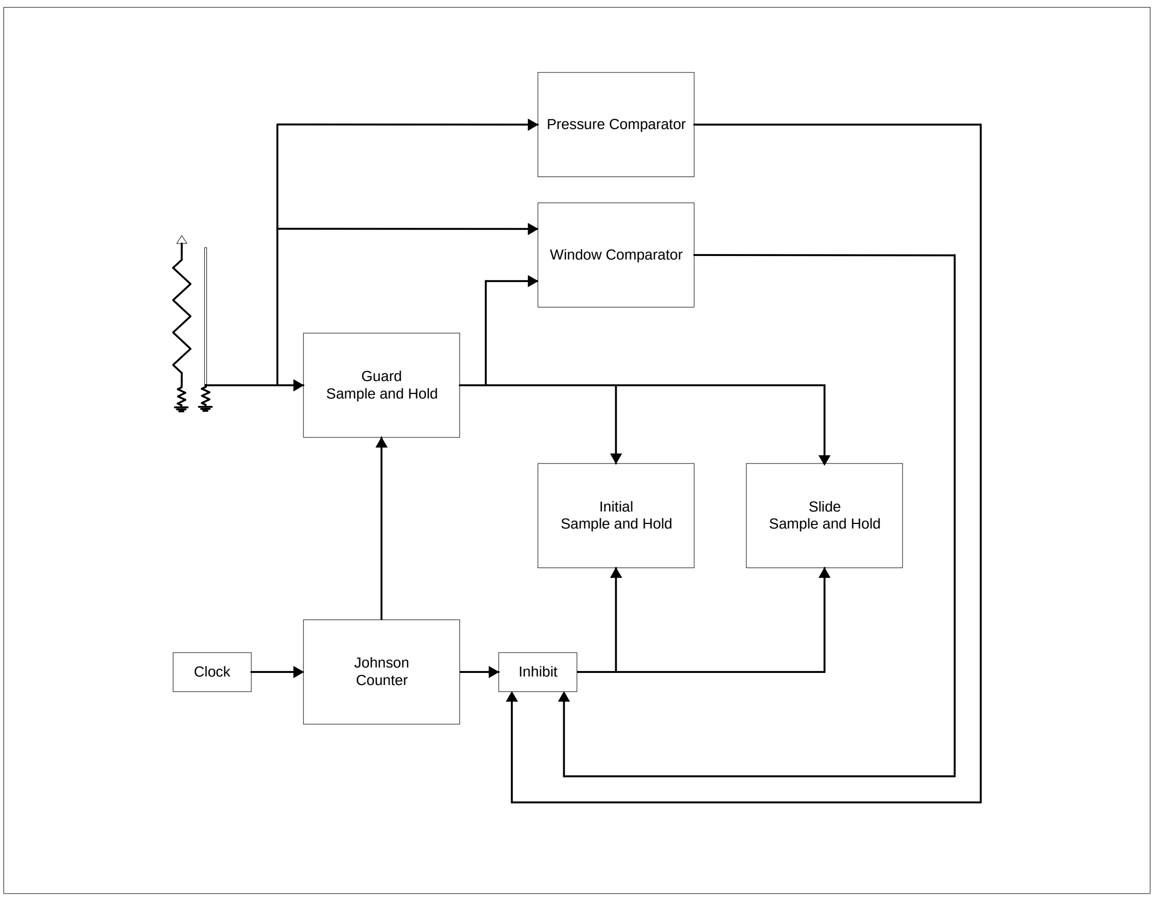


Figure 15: The Appendage Sample and Hold System

The Guard Sample and Hold begins constantly sampling the tap voltage at an extremely high rate as soon as power is applied to the Appendage. The input of the Guard Sample and Hold and the output of the Guard Sample and Hold are each fed to a window comparator circuit. The window comparator is a special form of comparator that ensures that a voltage applied to it falls between two values. If the voltage falls outside of either of those values, a signal is generated on the output of the window comparator.

In this case, the window comparator is looking at the difference between the input and the output voltage of the Guard Sample and Hold. If there is no change on the tap voltage, the voltages on the input and the output of the Guard Sample and Hold are the same. Once voltage changes on the Guard Sample and Hold input, there will be a difference between its input and its output until the Guard Sample and Hold is clocked – then the value on its input will appear on its output, and the voltage difference again will be zero volts.

The tap of the ribbon feeds the Guard Sample and Hold. So, when the ribbon is pressed, the Guard Sample and Hold will initially have a difference on its input and output. When this occurs, the window comparator system detects this difference, and if the difference is great enough to "fall out" of its window of reference, a signal is generated on the output of the window comparator.

The Guard Sample and Hold is clocked by one output of a Johnson counter. The other output of the Johnson counter follows this first clock signal by a discrete amount of time. This second signal is used to clock the Initial Sample and Hold and the Slide Sample and Hold. The input to both of these sample and hold systems is the output of the Guard Sample and Hold. If the output of the window comparator indicates that the input to the Guard Sample and Hold is at a different voltage than the output of the Guard Sample and Hold, the Initial Sample and Hold and the Slide Sample and Hold are prevented from sampling the output of the Guard Sample and Hold.

The result of all of this hoopla is the main signal sample and hold systems, the Initial Sample and Hold and Slide Sample and Hold, do not sample a signal that is very rapidly changing, or a signal that is present without the Pressure Comparator indicating pressure on the ribbon. The signals that meet the criteria of very rapid change are initial application of pressure, initial release of pressure, "bounce" signals from the tap and abrupt hammer-on/hammer-off signals. In the case of a bounce signal or rapid drop in voltage that occurs upon release of pressure, the pressure comparator signal will also fall, indicating to the system that pressure has been released and no other samples will be taken, including this last rapid change. In the case of a bounce signal that occurs when pressure is first applied, or for hammer-on/hammer-off voltages, the sampling will resume as soon as the window comparator indicates that the input and output voltages of the Guard Sample and Hold are in agreement (meaning the signal is stable). Changes in voltage resulting from even quickly sliding the pressure point do not move rapidly enough for the window comparator to become excited. Thus, the Initial Sample and Hold and Slide Sample and Hold systems do not get a chance to sample erroneous "bounce" voltages and hold the voltages before they are allowed to drop upon release.

Now that all of that is out of the way, we'll explore the action of the two signal sample and hold systems and why they generate three instead of two unique voltage outputs.

First, let's examine the Initial Sample and Hold system. The Initial Sample and Hold is only clocked one time per "pressure event". A "pressure event" is as a fancy way of saying "the interval from when pressure is first applied until it is released completely". In other words, if you press the ribbon with a finger, do your thing, then release pressure so that nothing again is touching the ribbon, that's a pressure event. So, the instant you press the ribbon, the Initial Sample and Hold immediately samples the voltage (as soon as the window comparator says it's OK). That means the Initial Output voltage goes to the exact value of voltage that corresponds to the position of pressure on the ribbon, and stays there. If you slide your finger around or hammer-on or hammer-off, the initial voltage output stays the same. It will only change once you have removed your finger from the ribbon and then press the ribbon again at some other point. In this manner, it is much like a keyboard that has, instead of 61 keys and a resolution of one half step per key (0.083V in a V/Octave system), it has more like a zillion molecules for keys and a resolution in zillionths of a volt.

The Slide Sample and Hold is sampled constantly during a pressure event. In other words, once you press the ribbon, it immediately begins to sample the voltage of the tap at an extremely high rate. As you slide your finger around on the ribbon and perform hammer-on/hammer-off maneuvers, the Slide Sample and Hold "tracks" the voltage as it changes. It is not a true "Track and Hold", but rather imitates one through a very high sample frequency. When pressure is released, the Slide Sample and Hold "freezes" the voltage. Therefore, the Slide Voltage output dynamically changes with the position of pressure and holds on release.

Now we get to the third signal, which is a very cool function. This third signal is the Bend Voltage. The Bend Voltage is simply the difference between the Initial Voltage and the Slide Voltage.

When pressure is first applied, the first sample taken by the Slide Sample and Hold is the same sample taken by the Initial Sample and Hold; the samples are taken simultaneously. So, right off the bat, the Bend Voltage is 0V. Let's say that pressure is applied at the 5V position on the ribbon. The Initial Voltage is at 5V and the Bend Voltage is at 5V. The difference between these two voltages is 0V; 5V (Slide) minus 5V (Initial) is equal to 0V. The Initial Sample and Hold has taken only one sample, so it does not change according to the position of pressure, but the Slide Voltage can change.

Without releasing pressure, sliding the point of pressure up one volt to the 6V position on the ribbon will raise the Bend Voltage to 1V; 6V (Slide) minus 5V (Initial) is equal to 1V. If the point of pressure is slid to the 4V position, the Bend Voltage will be -1V; 4V (Slide) minus 5V (Initial) is equal to -1V.

Thus, *wherever you initially touch the ribbon becomes the 0V point for the Bend Voltage, and the voltage will bend positive or negative from that point.*

This function is very useful in controlling the pitch through the mixed output function of the Appendage (which will be described shortly). However, it is also very useful in conjunction with some other form of pitch control, such as a keyboard. By applying the Bend Voltage to the bend input of a keyboard, one can bend up or down using the ribbon, without having to remember where the zero point of the ribbon is – the zero point is wherever you place your finger!

Mixed Output Function

All four voltage outputs – Initial, Slide, Bend and TFS – are available as separate outputs. Optionally, the inverted versions of these voltages are also available as separate outputs.

The Initial, Slide, and TFS voltages are scaled to output voltages from 0 to +10V (though it is possible to calibrate these voltages to lower maximum levels). The Bend Output can range anywhere from 0V to +10V to -10V. The scale of all of these voltage outputs is fixed – in other words, there is no control provided to attenuate these signals. The intended function of these voltage outputs is to feed devices that have input level controls – filter cutoff, modulation level, etc.

For pitch control, it is desirable to also be able to scale the voltage output for the task at hand. As an example, if the Slide Voltage were to be used to control pitch, and is not scaled down, the range of the ribbon would be 10 Octaves in a Volts-per-Octave system. This would allow the ribbon to control pitches ranging from sub-audible to supersonic. Unless the intended audience consists mainly of whales and bats, it would be advisable to provide some method of scaling the ribbon to some specific range.

Generally ribbon controllers do allow the ribbon to be scaled for a particular range, and the Appendage is no different, though it goes about the task in a slightly different way. A generic ribbon controller provides a single positional voltage for pitch control, a voltage that is generally analogous to the Appendage Slide Voltage. So, a range control involves constricting the maximum pitch voltage to some particular voltage. For example, if the range is set for 2 volts maximum, the ribbon will cover a two octave range; if the range is set for 6 volts maximum, the ribbon will cover a six octave range, and so on.

Any of the voltages produced by the Appendage can be used for pitch control. Additionally, because each voltage has a unique property that distinguishes it from the other voltages, these voltages can be combined and scaled to provide a wide range of response characteristics from the ribbon.

To accomplish this, the Appendage provides the Mixed Output function. This function allows each voltage to contribute to the task of pitch control in continuously variable ratios. Additionally, the Mixed Output section allows the introduction of external signals to contribute to the Mixed Output signal of the Appendage. Finally, the Mixed Output can be offset up or down in voltage, allowing the minimum and maximum voltage to span the range between two continuously variable values, rather than just zero volts and some maximum value. To illustrate the effect of the Mixed Output function, some examples are given.

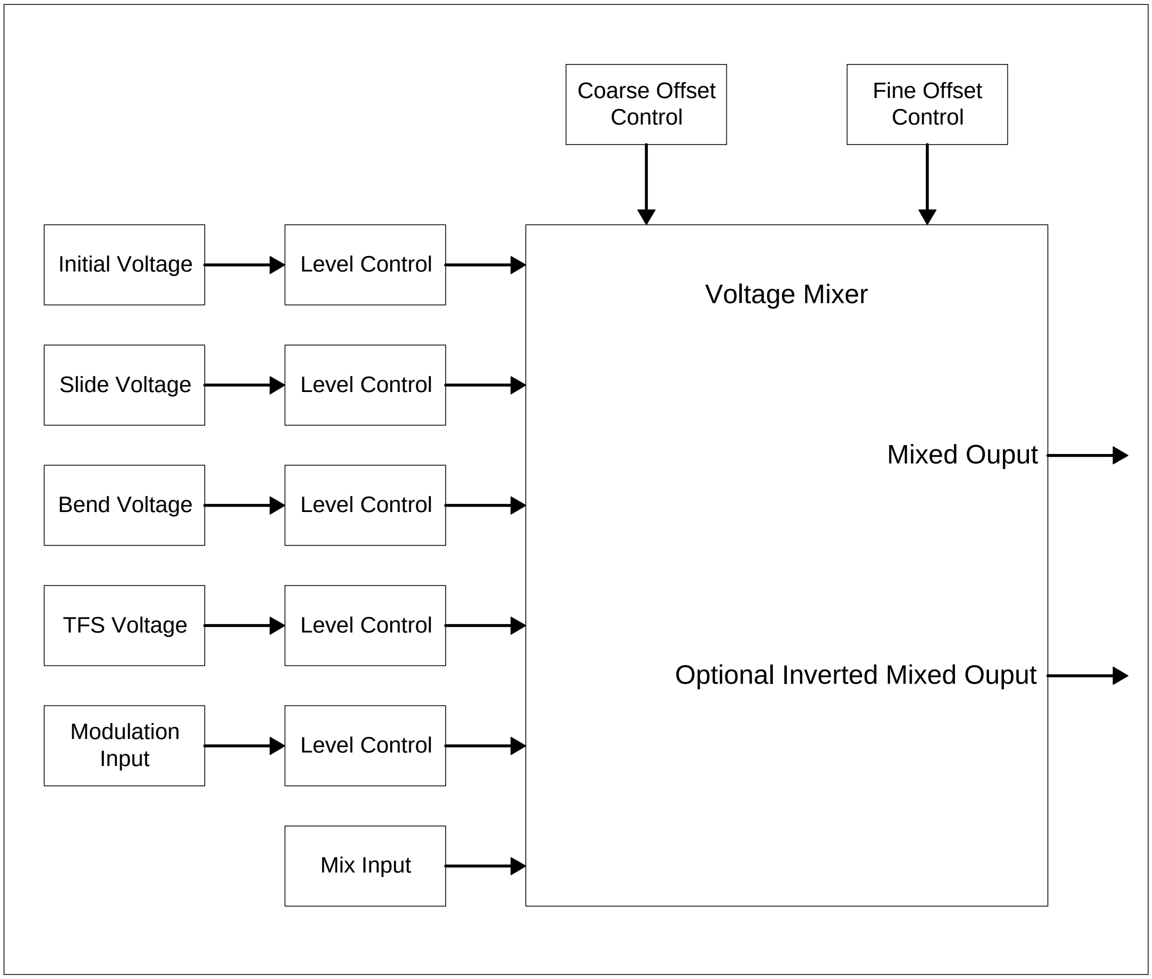


Figure 16: The Mixed Output Section

Generic Ribbon Controller

To duplicate the action a of a generic ribbon controller, consider the Slide Voltage Level control. By turning all other level controls down, and simply adjusting the Slide Level control, the control range of the ribbon can be set. For example, if the level is adjusted for a 4V range, and the offset controls are at center position, sliding from the “bottom” of the ribbon to the “top” of the ribbon will result in a 4V slide. When connected to a V/Oct VCO, this would result in a continuous four octave slide. Wherever the pressure is applied on the ribbon, the Mixed Output will provide the voltage relative to that position when using a 4V range, and sliding up or down will provide a slide up or down relative to the actual position of the slides.

Fixed Note Ribbon Controller

Setting the Initial Note level control to a particular range allows the ribbon to produce fixed notes throughout that range. For example, a 6V range will allow the ribbon to produce a note anywhere within a six octave range whenever the ribbon is pressed. Sliding up or down will not alter the Mixed Output voltage, and thus will not alter the pitch of a VCO that the Mixed Output is controlling. This action is much like playing a keyboard, only, of course, there are no keys. This setup is conducive to producing dynamic timbre changes without altering pitch: for example, filter sweeps. The pitch is set by the initial contact, and the Bend, Slide, and/or TFS outputs can be used to sweep the cutoff of a filter without altering the pitch of the note.

Disproportionate Bend Pitch Controller

A very useful and versatile setting is the mixture of the Initial and Bend voltages. The Initial voltage level control is used to set the range of the ribbon. For example, say the Initial voltage is set for a 4 volt range. The ribbon will provide a four octave response as long as the ribbon is pressed, and the position is not "slid" up or down. By introducing bend voltage in varying amounts, the slide response can be altered for non-proportional slides. As an example, if a small amount of Bend voltage is introduced, sliding a large distance up or down from the pressure point produces only a small amount of bend – the pitch of the VCO during slides will not track the position of the pressure. This is useful for creating low "wailing" types of bending around a fixed note. As the Bend level control is increased, sliding the pressure point will produce more and more bend for the same amount of movement on the ribbon. Using this method, an easily controllable method of bending notes is made possible. Turning up the bend voltage even more can produce very sharp bends for an increasingly small amount of movement – this provides a method for producing vibrato by barely moving the point of pressure back and forth, such as rolling the finger or through subtle motions of the wrist. It's entirely possible to reduce the amount of Initial Voltage to some small range and the Bend Voltage to a wide range so that the initial pitch range is constricted, but sliding provides a greater, more dramatic shift in pitch. This configuration allows slides that far exceed the range set by the Initial level control.

Bend Controller

If all other voltages are turned down, and the Bend level is increased, each time the ribbon is pressed, the initial pitch will be the same pitch, regardless of the position on which the pressure is applied; pressing the bottom, middle, or top of the ribbon will result in the same pitched note. However, sliding the position up or down will slide the pitch in the same direction, in an amount dialed up by the Bend level control.

"Super Slide" Controller

If the Bend and Slide level controls are turned up and the Initial level is turned down, the Slide voltage will determine the initial pitch. However, because both voltages move in the same direction, sliding will produce very radical shifts in pitch.

TFS Controlled Slide

If the Initial and TFS levels are turned up, the range of the ribbon is set by the Initial level. Just as with the Initial Note Ribbon Controller example, the pitch will not change while sliding a single pressure point. Fixed notes can be easily played. If the Slide or Bend outputs are connected to a VCF, sliding can sweep the filter, but not the pitch.

However, once a second pressure point is placed on the ribbon, the TFS voltage can be used to slide up and back down to the current pitch. Note that high levels of TFS voltage will bend the initial note by some amount, depending on how much finger "width" is placed on the ribbon. This can be avoided by pressing with as little surface area as possible. This effect can be taken advantage of by producing vibrato by increasing and decreasing pressure on the ribbon (which has the effect of increasing and decreasing how much of the fingertip is pressing the ribbon).

Right Note Priority In Current Mode Using TFS Voltage

In the current mode, the ribbon only reacts to left hand hammer-on/hammer-off movements. The TFS voltage is linear and provides a good way to get right hand linear hammer-on/hammer-off intervals. To do this, the interval can be set using the TFS level control. Hammering on to the right will mix in a proportional amount of TFS voltage, thus raising the pitch the expected amount.

External Modulation

Any signal can be introduced to modulate the Mixed Output signal. The level control allows the level of modulation to be continuously adjusted.

External Mix

The External Mix control is an un-attenuated signal input designated for the input of signals intended to be modulated by the Appendage. For example, a keyboard or sequencer control voltage can be inserted into this connection. One application would be using the bend voltage to provide pitch bends to a keyboard voltage. In this case, the Mixed Output would be connected to the device(s) intended to be controlled by the keyboard.

The mixture of controls is continuously variable. And, as mentioned in the Initial controller examples, all of the individual outputs are active, regardless of the settings of the mix controls – these outputs can be used to control various functions of a musical system in conjunction with the Mixed Output signal.

Gate and Trigger Functions

The gate and trigger functions generated by the Appendage are just as important to its Appendageness as the control voltages it generates. Obviously these signals are used to synchronize external modules to the various control voltages the Appendage generates. The nature of the system used to generate these voltages lends itself to also providing a bit of diversity to not only how the output signals behave, but also to how the Appendage reacts to *input* gate signals. External gate signals allow the Appendage to integrate with external devices in a few different ways.

Here we get into a bit of a gray area in the discussion – in order to describe some functions, one has to have an idea of other functions not yet mentioned. We'll give it our best shot here and not try to lose track of where we are in the discussion. If, of course, that is at all possible.

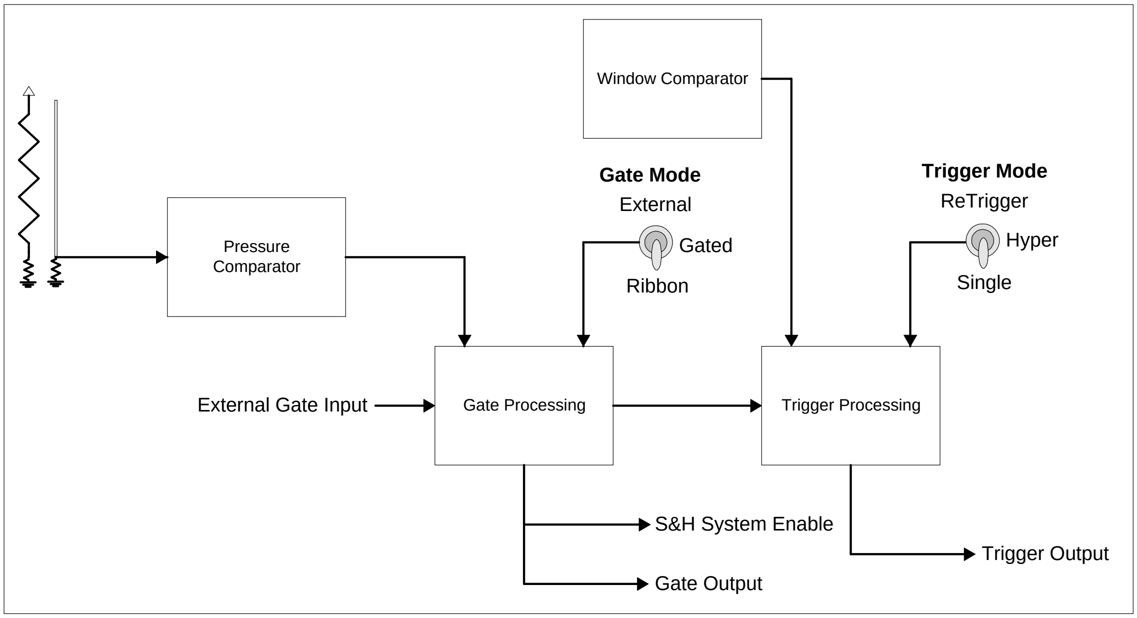


Figure 17: Gate and Trigger Signal Processing

The Gate Mode and Trigger Mode switches are included in Figure 17 in hope of making the following description a bit more clear.

First of all, notice that the Pressure Comparator signal passes through the gate processing section on its way to the sample and hold system. Remember – the Initial and Slide sample and hold circuits are not allowed to sample until pressure is detected. Or are they?

The gate processing section allows the External Gate Input to work in conjunction with the Pressure Comparator, or totally bypass the Pressure Comparator, depending on the position of the Gate Mode Switch. This setup confers upon the External Gate Input the supreme power of Sample Enable. Therefore, the Pressure Comparator alone can determine when samples are taken (and gates are generated), or the Pressure Comparator and External Gate Input can work together in a bi-partisan manner to determine when samples are taken (and gates are generated), or the External Gate Input can enact a coup and become solely responsible for when samples are taken (and gates are generated). Of course, the supreme leader, the Window Comparator, has ultimate veto power, but even its powers are limited to what the Gate Mode Switch is up to.

The Gate Mode Switch has three positions: Ribbon, Gated, and External.

Gate Mode Switch Ribbon Position

When the Gate Mode Switch is set to the Ribbon position, everything works as described up to this point in this document. When pressure is applied to the ribbon, the Gate Output goes high, and the sampling system which controls the Initial, Slide and Bend outputs goes into action. When pressure is completely removed from the ribbon, the Gate

Output goes low, and the Slide and Bend voltages "freeze" (the Initial Voltage was frozen instantly right after the pressure was applied).

Gate Mode Switch Gated Position

Setting the Gate Mode Switch to the Gated position allows the External Gate Input to work in conjunction with pressure on the ribbon. The External Gate Input can be fed with anything that goes above and below a volt or so – squared signals are preferred. A keyboard or sequencer gate, an LFO or a VCO will do the trick. But, rest assured, a valid external gate signal must be applied to the External Gate Input for this mode to work.

The "Gated Position" allows the Appendage sample and hold system to only acquire voltages while pressure is applied to the ribbon AND the signal applied to the External Gate Input is high. For example, if a 1 Hz LFO is connected to the External Gate Input, and no pressure is applied to the ribbon, the Appendage will do nothing – it will not sample or produce gate or trigger signals. As soon as pressure is applied to the ribbon, the sample and hold system will begin sampling and the gate and trigger outputs will produce gates and triggers. Note that, each time the external gate signal goes high, a new Initial sample is taken, the Slide and Bend voltages slide and bend, the gate output goes high, and a trigger signal is generated. Each time the external gate signal goes low, the Slide and Bend voltages freeze and the gate goes low. Likewise, if the external gate signal is high, and pressure is withdrawn from the ribbon, the Slide and Bend voltages freeze, and the gate drops low.

This mode allows the Appendage to produce an arpeggio-like effect when sliding – the continuous slides are "broken up" by the external gate into discrete notes. The voltage, gate and trigger outputs can be synchronized to an external device, such as a sequencer or a keyboard. For the as-yet-un-discussed external signal input functions, this mode allows automated sampling to occur when only the ribbon is pressed.

Gate Mode Switch External Position

The External position of the Gate Mode Switch allows the external gate signal to totally control when samples, gates, and triggers can occur. When the gate signal goes high, the Initial Voltage is sampled and a trigger is generated. As long as the gate signal is high the Slide and Bend voltages are tracking the ribbon and the gate output remains high. When the external gate signal goes low, the Slide and Bend voltages freeze and the gate signal goes low. All of this occurs whether the ribbon is pressed or not. This means that, if the ribbon is not pressed, and it is the signal source, this mode actually causes the lowest voltage value to be sampled each time the gate goes high. This does lend itself to a certain style of manipulating the ribbon voltages, but is generally more useful when sampling external signals (which will be covered later in this document).

Having covered the gate functions, let's focus a bit more on the trigger functions. Figure 17 includes the Window Comparator in its diagram – this may have been a source of confusion when the diagram was first examined. After all, the Window Comparator is used in the sampling system, is it not? Yes it is, but two triggering modes take advantage of the signals the Window Comparator provides to facilitate re-triggering.

First of all, “re-triggering” should be clearly defined for purposes of explanation. Each time a gate signal is generated, by whatever means, a 5 mS (.005 second) wide trigger pulse is also simultaneously generated. Assuming the Appendage Gate Mode Switch is in the “Ribbon” position, this means if the ribbon is pressed to produce a gate, one trigger is produced. If, while pressure is still applied, and a second pressure point is introduced (hammer-on), the gate remains high but no other triggers are generated.

If there is re-triggering, then when the second point of pressure is applied (hammer-on), a new trigger signal is produced. This allows hammer-ons to sound as individual notes or as accents to longer notes if the Trigger Output is connected to an envelope generator.

The Window Comparator actually produces two signals internal to its operation: it produces a high signal when it detects an instantaneous rise in voltage at the ribbon tap, and it generates a high signal when it detects an instantaneous drop in voltage at the ribbon tap. Hammer-ons and hammer-offs produce instantaneous shifts in the tap voltage, so they are detected by the Window Comparator. These signals are used in the generation of the “Re-Trigger” and “HyperTrigger” modes of trigger operation.

A signal is shown in Figure 17 originating in the gate processing section and going to the trigger processing section. This generally means that triggers are only produced while the gate signal is high.

The Trigger Mode Switch has three positions: Single, Re-Trigger and Hyper

Trigger Mode Switch Single Mode Position
The Single Mode Position allows the Appendage to generate a trigger only when the Gate Signal goes high. This is true of whether the gate goes high because of pressure on the ribbon or the Appendage is in one of the two external gating modes and the gate goes high. Applying a second point of pressure will not produce an additional trigger.

Trigger Mode Switch Re-Trigger Mode Position
The Re-Trigger mode will produce a second trigger when a hammer-on (second point of pressure) is applied above the initial point of pressure, causing the tap voltage to rise, or when a hammer-off causes a rise in tap voltage (removing a point of pressure below a second point of pressure). Note that in Current Mode, generally the second trigger can only occur removing a pressure point below a higher point of pressure (hammer-off); remember that the current mode has left hand priority on the tap voltage, so hammering on “above” the current pressure point will not shift the voltage of the tap up. In practice, the internal workings of the Window Comparator can detect the momentary shift in current, and will produce triggers at certain intervals in spacing from the lower pressure point.

Re-trigger works whether the gate is generated by the ribbon, a combination of ribbon and external gate signal, or when the external gate signal alone is high, depending on the gate mode.

Trigger Mode Switch Hyper Mode Position
The HyperMode trigger will produce a trigger if you look at the Appendage cross-eyed. Well it's not quite that sensitive, but, while the gate is high, the following applies:

1. Initial pressure – trigger occurs.

2. Removal of initial pressure – trigger occurs.

3. Hammer-on – trigger occurs.

4. Hammer-off – trigger occurs.

Again, the same caveat for current mode operation applies: hammer-ons above the lowest point of pressure will produce triggers at certain intervals of ribbon length. Voltage mode is balls-to-the-wall.

The Hyper-Trigger mode is very useful for very fast runs of notes, particularly when using a trigger-operated attack-decay envelope generator. It is also useful for really whacking the hell out of a drum voice. Remember, when operating HyperTrigger, to not paint yourself into a corner: If you've finished an exhilarating run of notes, and you wind up with pressure applied, you better switch to some other trigger mode, because you're going to get an extra note and spoil the mood when pressure is released ….

HyperTrigger works whether the gate is generated by the ribbon, a combination of ribbon and external gate signal, or when the external gate signal alone is high, depending on the gate mode.

AutoGlide – The Rubbery Glide of Doom

A while back, it was mentioned that the Appendage was intended to do "Groovy" things using two points of pressure (hammer-on, hammer-off). One of the groovy things, for which debt of gratitude is owed John Simonton (his writings turned me onto the idea), is the use of current through the ribbon to produce a unique response (what came to be the TFS signal in the Appendage). The other thing is an addition to the Appendage called "AutoGlide".

The function of AutoGlide is really not a new thing, at least when used with keyboard controllers. Often it is referred to as "legato portamento" or something along those lines. Basically, it is a specialized portamento system that only kicks in after one key has been held down – the first note does not glide, but all subsequent notes that are played while a key is held down do glide. This is pretty much what AutoGlide does, except there is no key on a ribbon to hold down.

Instead, of course, there's a pressure point to hold down. So, that initial pressure point is the "key" that starts AutoGlide's function; the glide kicks in after that initial poke at the ribbon.

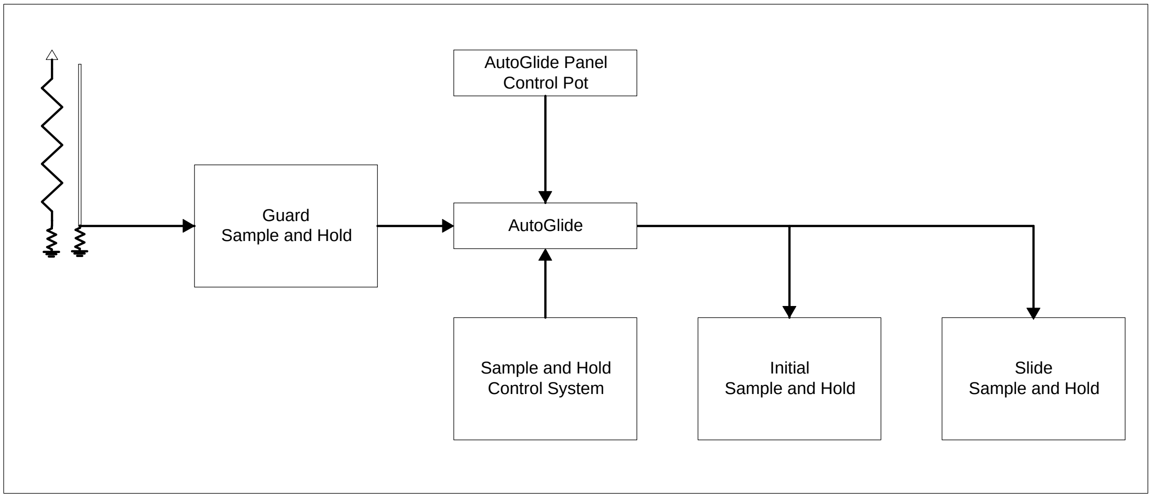


Figure 18: The Appendage AutoGlide Function

In Figure 18, we see a new twist in the sample and hold system – between the Guard Sample and Hold and the Initial Sample and Hold and Slide Sample and Hold, we see the signal actually passes through the AutoGlide function. Though the Initial Sample and Hold is fed by this signal, AutoGlide will have no effect upon it: the voltage never changes during a pressure event, so there is nothing to glide.

The Pressure Comparator, Window Comparator, and Gate System have all been condensed to a functional block called "Sample and Hold Control System". The signal leading from that block to the AutoGlide block is simply the signal that tells AutoGlide to glide.

At the instant that pressure is applied to the ribbon, the AutoGlide section does not lag the voltage – this allows the initial value of the tap to be sampled by both the Initial Sample and Hold and the Slide Sample and Hold systems. Therefore both of the sample and hold systems start out at the same value, thus ensuring the first note doesn't glide and that the Bend zero point is at the initial position of pressure. The instant after the first sample is taken, however, the Sample and Hold Control System "kicks on" the amount of glide that is set by the AutoGlide Panel Control Pot. All subsequent movement of the Slide and Bend outputs during the pressure event will then glide from point to point. It is particularly effective for hammer-on and hammer-off technique. Each initial note does not glide from point to point, but once one pressure point is applied, hammering-on or hammering-off produces a glide to the new value, rather than a discrete step to the new value. It provides a nice, rubbery feel to operating the ribbon. Rapid hammer-ons and hammer-offs now more closely resemble quick vibrato rather than trills, for example. A number of other bendy effects can be accomplished using AutoGlide.

The TFS voltage is not affected by AutoGlide, because the TFS voltage does not originate from the sample and hold system. This condition actually allows some great effects on its own: during current mode operation, if TFS is set in the mixed output to contribute to pitch control, any hammer action (up or down) performed to the right of the initial pressure point will not glide – these movements in voltage are provided by the TFS voltage. But any Slide or Bend hammer action performed by the left hand will glide, because Slide and Bend do originate from the sample and hold system. It's a great effect. Try it.

Another practical use (and actually the original intent of AutoGlide) is that it can be used to prevent detuning upon release of the ribbon when very high levels of Slide and Bend are dialed in. With those voltages set high, "finger-squish" (the amount of surface area the finger covers) can alter the point of contact with the ribbon as the finger is removed if one is not careful. Turning up AutoGlide will cause this effect to be greatly reduced because it retards the Slide and Bend voltages response to rapid changes in voltage – the effect is then similar to the lag technique used in John Simonton's design.

Voltage and Current Operation

The differences between operating in voltage mode and current mode have already been beaten up quite a bit earlier in this document. What remains for discussion on the subject is a clarification of how the modes are switched and how the signals themselves are routed and scaled.

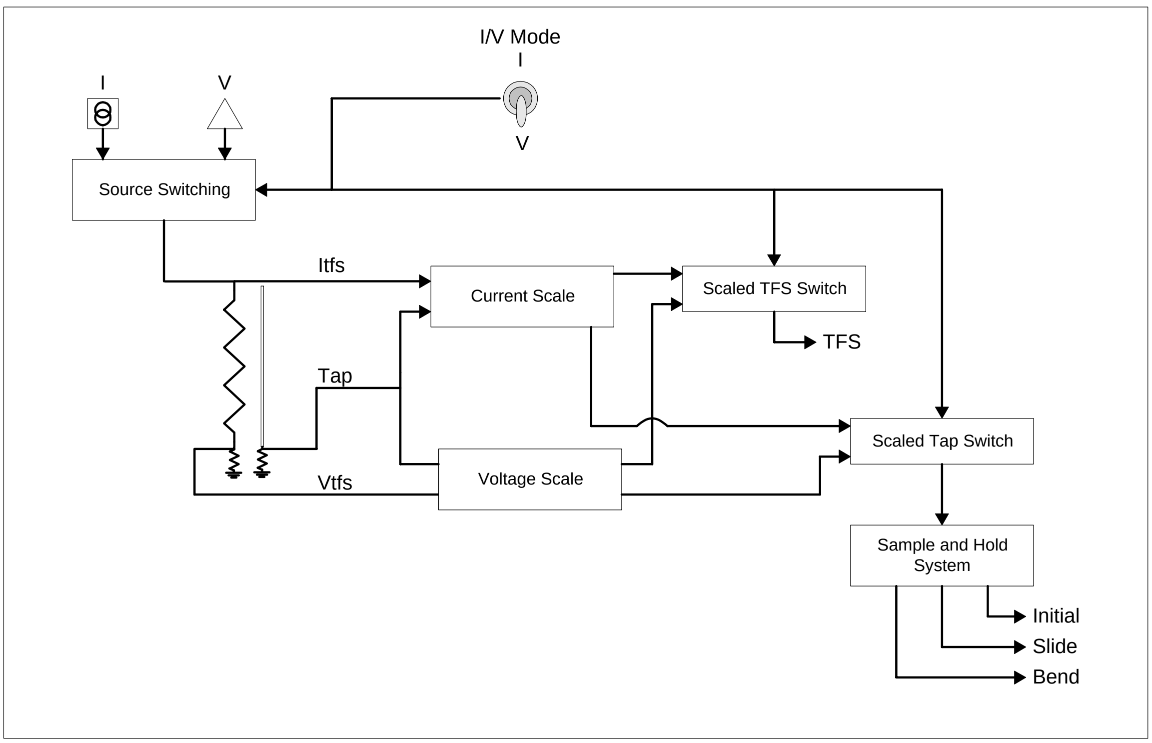


Figure 19: Appendage Ribbon Voltage Mode and Scaling Functions

In Figure 19 it can be seen that the Appendage is placed in either Voltage (V) mode or Current (I) mode of operation by switching the I/V Mode Switch either to V or I.

Setting this switch actually controls three internal switches simultaneously. The first section of the switch (Source Switching) selects between placing a regulated voltage source or a constant current source at the top of the ribbon.

The second section of the switch (Scaled TFS) is used to select between the current mode TFS signal and the voltage mode TFS signal.

The third section of the switch (Scaled Tap) is used to select between the current mode tap signal and the voltage mode tap switch for routing through the sample and hold system.

There is enough of a difference between the voltage mode and current mode levels that require them to be scaled separately, hence the voltage scale and current scale sections. The TFS is switched separately because it is not routed through the sample and hold system, whereas Initial, Slide and Bend are derived from the sample and hold outputs.

The output voltages are then routed to their separate connectors and to the mixed output section.

External Sample and Hold Functions

As the Appendage was being developed, it couldn’t help but be noticed that a fairly unique sample and hold system had also come into being to facilitate the desired ribbon functions of the Appendage. Not only does the system sample and track in concert, but it also, through necessity, has an exceedingly low droop rate. The AutoGlide function only adds to the oddity of the system. The thought was that the Appendage, if anything, is an odd duck in the world of ribbon controlled devices, so why not extend that eccentricity in just one more direction? Thus, the external sample and hold function was born.

The external sample and hold functionality of the Appendage takes advantage of the fact that it does have a ribbon, and that ribbon provides a nice method of interacting with the sampling and the holding and the pushing and the shoving and the geflavin.

So, the External Signal Input was born. This input is alternately switched to two different points of the circuit to accomplish different ends to the means.

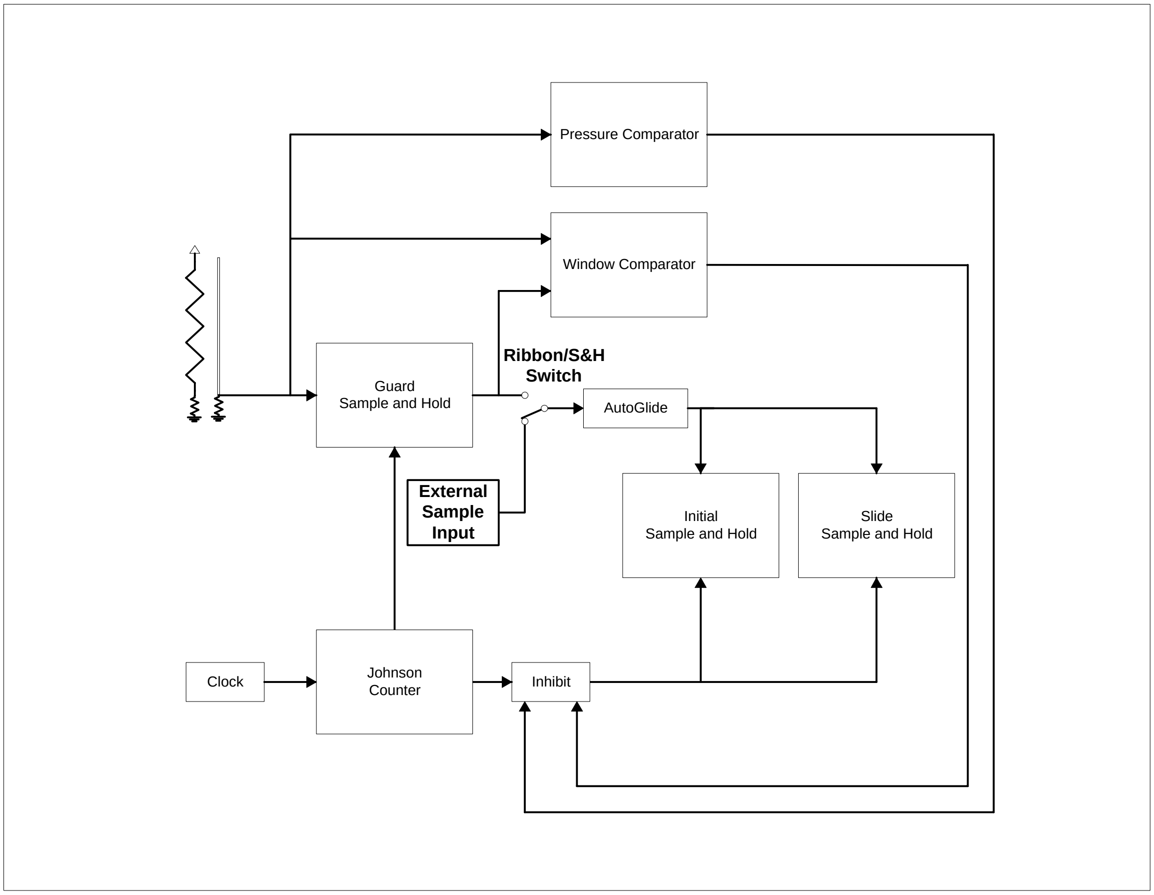


Figure 20: External Sample and Hold Mode

In Figure 20, one can see that the Ribbon/S&H switch will inject an external signal straight into the sample and hold system through the AutoGlide function. The path of the output of the Guard Sample and Hold to the other two sample and hold systems is completely bypassed in this case. However, the input to the Guard Sample and Hold is not bypassed and its output is still connected to the comparators; this allows the ribbon, in combination with the gating and triggering modes, to decide when and how samples are taken. In other words, the user of the Appendage has a bit of latitude as to deciding if the samples are to be taken from time to time, repeatedly taken for short or long bursts, or to be fully automated as with a standard clocked sample and hold. By logical extension, of course, it follows that the original gate and trigger output functions, as well as the AutoGlide function, are still maintained, whether the ribbon is feeding the sample and hold system or an external signal is feeding the sample and hold system.

The Appendage voltages that are produced by the sample and hold system maintain their functions as well. The difference is, instead of a sampling a fixed voltage, the Initial and Slide systems are sampling a moving target (provided, of course, the signal on the sample and hold input is not a stationary voltage).

The Initial Sample and Hold system still acts as a standard sample and hold – it will only take one sample at the beginning of a pressure or external gate event. The Slide Sample and Hold system still emulates a track and hold function, so it will begin tracking the external input system at the beginning of a pressure or external gate event and will hold when the pressure event has ended, or the external gate has fallen low (depending on how the gating mode is set). Of course, that means the Bend output also acts as a track and hold; the Slide output will track the actual range of the input signal, and the Bend output will track the level of the input signal, but above and below a zero point as set by the Initial sampled level.

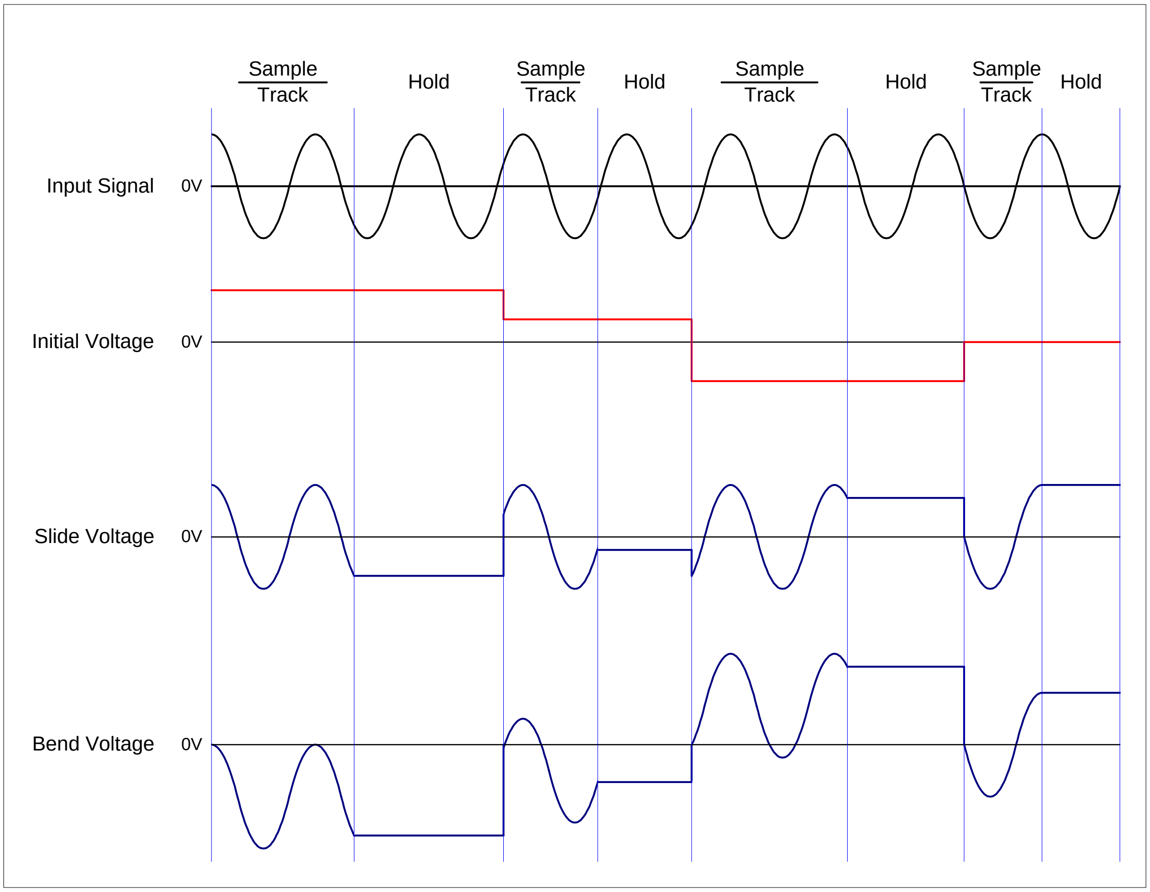


Figure 21: Sample and Hold Output Characteristics

OK, that last sentence could probably use a bit of explanation, vis-à-vis what the Bend Output is doing. Observe Figure 21: the movement of the Bend Output will more or less match the movement of the Slide Output, but, because the Bend Output is a product of the difference in voltage between the Initial Sample and Hold and Slide Sample and Hold systems, it will exhibit larger swings around zero volts.

Because voltage (or current, depending on V/I Mode) is still applied to the ribbon, the TFS function is still active during sample and hold operation. This gives an extra element of control of what is going on during a sample and hold fest. If the mixed output is used to connect the sample and hold signals to some device such as a VCO, for instance, the TFS function can be used to move the general pitch of the VCO while sampling is taking place. Of course, the individual TFS Output can be connected to any voltage controlled device as well during sample and hold operation.

The Gate Mode Switch is used to set the mode of control for the sample and hold operation. It probably wouldn't hurt to go over the gate modes again, only, of course, with an eye towards sample and hold operation rather than ribbon operation.

Gate Mode Switch Ribbon Position
Setting the gate mode to Ribbon allows the user to completely control the rate and duration of sampling. When the ribbon is first pressed, the Initial sample is taken and the Slide and Bend outputs begin tracking the signal input, and continue to track the input voltage until the ribbon is released. When pressure is released, the Slide and Bend outputs "freeze" with their current values. The gate and trigger functionality of the ribbon mode remains unchanged – the gate output will stay high as long as pressure is applied to the ribbon, and the trigger operation will operate as set by the Trigger Mode switch.

Gate Mode Switch Gated Position
The Gated mode of operation requires an external gate input. Nothing happens until the ribbon is pressed. Once the ribbon is pressed, the external gate signal must be high for sampling operation to take place. If the ribbon is pressed and the external gate signal is high, the Initial sample is taken, and the Slide and Bend outputs begin tracking the signal input. If the ribbon is released or the gate goes low, the Slide and Bend outputs hold their current values. Thus, the gated mode acts more as a "normal" clocked sample and hold module, except the operator can control when the samples are clocked by applying and withdrawing pressure from the ribbon. A gate and trigger output signal will be generated with each sample taken. The Re-Trigger and HyperTrigger modes operate as expected when the external gate signal is high.

Gate Mode Switch External Position
The External Gate mode, when using an LFO as the gate input, allows the Appendage to clock continuously in the same manner a normal clocked sample and hold module operates. Pressing the ribbon will have no effect on when samples are taken – the sample and hold circuits are only clocked by the external gate signal. Again, the Re-Trigger and HyperTrigger modes operate as expected when the external gate signal is high.

Because the external sample and hold signal is inserted into the system through the AutoGlide section, AutoGlide is active during sample and hold operation. It functions in the same manner – there is no lag imparted to the input signal until the split second after the Initial sample is taken for each sampling event. After that, while the Slide and Bend voltages are tracking the input signal the AutoGlide will lag these voltages according to how much lag the AutoGlide control is set for.

Sampling Smooth Voltages

There is an additional switch that adds more functionality to the sample and hold mode: the S&H Mode Switch. This switch selects between External Sample and Hold (the sampling mode discussed up to this point) and a mode called "KBD" (keyboard) sampling.

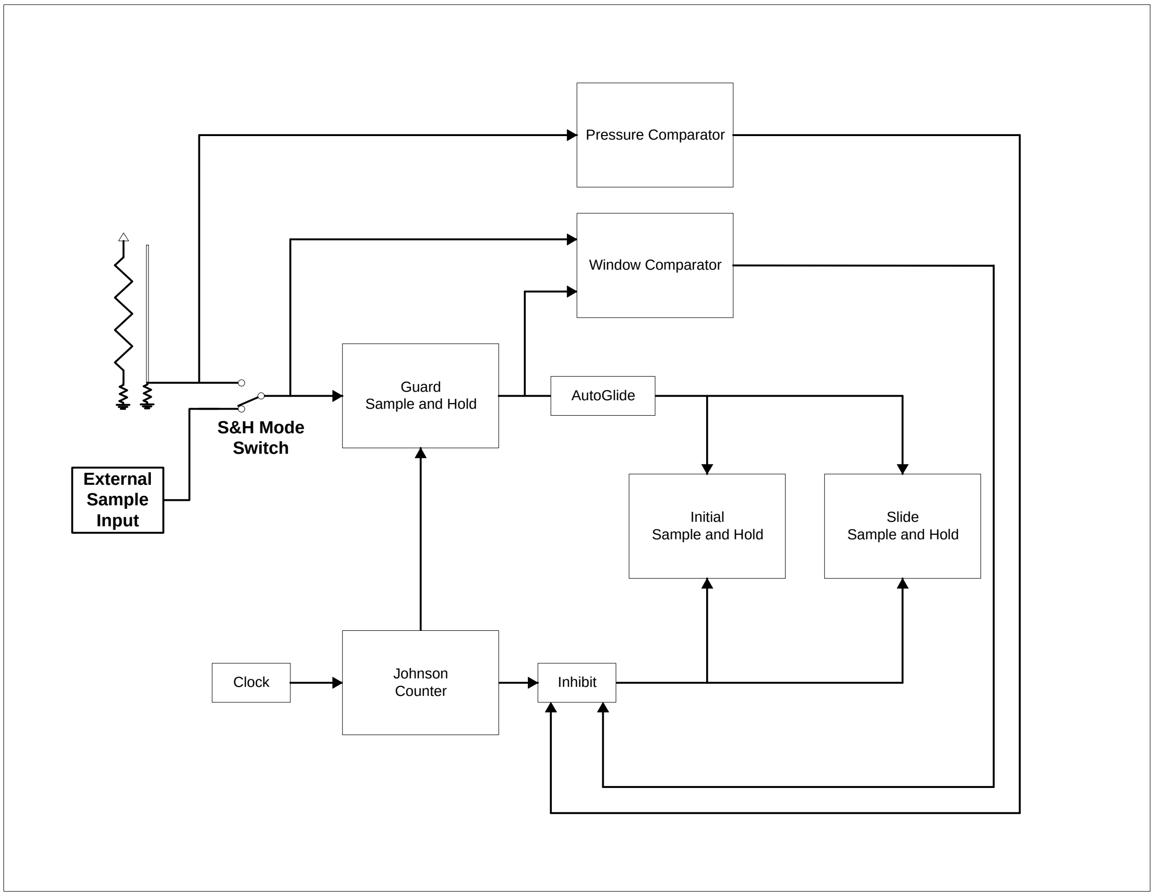


Figure 22: KBD Sampling Mode

In truth, both sample and hold modes sample external signals, but the signals intended for the "KBD" mode belong to a specific type of input signal – "smooth" pitch voltages of the type generated by keyboards and sequencers. Figure 22 shows the difference between the "KBD" mode of sample and hold and the external mode of sample and hold.

When the Sample and Hold Mode Switch is set to "KBD", the signal input is directed straight into the Guard Sample and Hold. If one recalls Appendage Theory, the Guard Sample and Hold's job, in conjunction with the Window Comparator, is to monitor the input signal and detect when a sudden change in voltage occurs. When a sharp rise or drop in voltage happens, this system inhibits samples from being taken. The control signals for generating gates and triggers are derived from this system. This allows the

Appendage to generate Gate and Trigger signals that are synchronized to what the keyboard or sequencer is doing.

OK, so…if the gates and triggers are synchronized to the keyboard, and the Appendage sample and hold system follows the control voltage of the keyboard, why bother? What's the difference? Two words answer that question: duophony and AutoGlide.

The duophony is really a sort of half-duophony, if that's even a word. The word processor used to write this document certainly doesn't recognize it as a word (but, then again, it has problems with "duophony", so there you go). Duophony is the ability of a keyboard to play two notes simultaneously, or rather, supply two control voltages and two sets of gates and triggers so that one can articulate two different notes. Well, the Appendage only supplies one set of gate and trigger signals, so that's out. But, it does transmit at least two control voltages. A duophonic keyboard allows one to play the two notes completely individually. The Appendage doesn't quite do that either. So what is it the Appendage will do then?

In the KBD sample and hold mode, if one connects a monophonic keyboard to the external input in the KBD mode, then connects the Initial and Slide outputs to two different VCOs, individually striking keys will allow both VCOs to track together. However, if one plays a note, then holds down that key and begins to play other keys while holding down at least one key constantly, the Initial output will hold its VCO at the first pitch and the Slide Output will allow its VCO to track the additional notes. So, two simultaneous notes are possible. If one mixes in the Bend Output to some other parameter, the difference in simultaneous notes is transmitted as a third control voltage (handy for filters and such).

Of course, sequencer voltages will follow the same course, as long as the sequencer is able to supply gate signals that overlap steps. The Klee Sequencer's gate merge function allows this to happen. The end result is that when an extended gate is generated, one VCO will lock to that pitch. As the sequence progress, the Slide VCO will track the sequence. When the external gate signal supplied by the Klee drops, then rises again, the Appendage will once again lock the two VCOs together and…..and so on and so forth. This method allows the Appendage to create mini "sub-sequences" out of a larger sequence. Of course "sub-sequences" are entirely possible just using the Initial output; in that instance, the Appendage is acting as a "normal" sample and hold, albeit with an extremely low droop rate. In other words, most sample and hold devices can perform that function.

Likely, though, most sample and holds do not generally perform the AutoGlide function, which is the other Big Reason this mode is supplied. Now, if one recalls AutoGlide Theory, one may remember that it is very similar to the "Legato Portamento" function of a keyboard. With this system, first pressing a key produces no glide, and pressing keys individually produces no glide between notes, but, if one presses more than one key, the notes will slide from one note to the next. This is a very expressive function, and the Appendage allows any CV keyboard to provide that function.

This function also applies to any pitch control device such as the sequencer. As long as the gate signal received by the Appendage is high, it will "glide" the notes.

In this mode, the gate output of the Appendage follows the external device's gate, and must be used in lieu of the external devices gate – the Appendage is synchronized to the AutoGlide function using this method. The trigger output mode changes slightly. The Appendage can "re-trigger" on the input signal by using the Guard Sample and Hold/Window Comparator signals to detect changes in input voltage that indicate a re-trigger should happen. In this mode, the HyperTrigger function now acts as a re-trigger signal. The HyperTrigger mode now triggers on the initial note and any change in the initial note will create a new trigger signal. In KBD mode, HyperTrigger does not produce an extra trigger when the key of the keyboard is released or when the sequencer gate drops low. If re-trigger is not desired, simply set the trigger mode to one of the other two settings.

To use the KBD mode of operation, the gate signal of the keyboard or sequencer must be connected to the external gate input, and the control voltage of the keyboard must be connected to the external signal input.

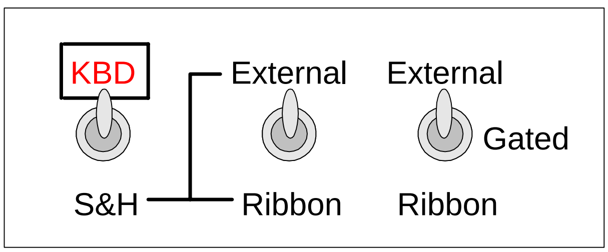


Figure 23: KBD Mode Switch Settings

The Appendage must be in sample mode, with the Gate Mode switch set to "External". As with the other external sample modes, TFS is still active, and provides an additional method to squiggle things around while all of the above is happening.

Conclusion

This pretty much is the end of the Appendage exposure. There are functional intricacies that allow the Appendage to unlock any voltage controlled synthesizer in many ways. Getting in touch with one's Appendage is a sure way to attain harmony with the universe and all living things. Or, it could just prove to be a groovy way of smacking your synthesizer around in a different manner than you ever have before. I'm not sure there is much of a difference between the two concepts.

-SS

Input Connections

Input	Function
External Sample In	Input for External Sampling – Used for S&H Modes
External Gate In	Input for External Gating
Mix Input	Signal input for mixing with ribbon/S&H output
Modulation Input	Applies modulation to mixed output
Ribbon	Input for Ribbon

Output Connections

Output	Function
Initial Note Voltage	Outputs Initial Position Voltage – Fixed Per Event (0 – 10V)
Slide Voltage	Outputs Continuous Position Voltage (0 – 10V)
Bend Voltage	Outputs Continuous Bend Voltage (+/-V relative to direction)
TFS Voltage	Outputs Voltage Relative to Two Pressure Points (0 – 10V)
Mixed Voltage	Outputs Mixed Voltages From Pitch Section
Gate	Outputs Gate Signal (+5V or +10V level)
Trigger	Outputs Trigger Signal (5 mS pulsewidth, +5V or +10V level)
Inverted Versions of All Output Voltages Available	

Potentiometer Controls

Control	Function
AutoGlide	Sets glide rate of AutoGlide function
Initial Mix	Sets amount of Initial Note voltage in Mixed Output
Slide Mix	Sets amount of Slide voltage in Mixed Output
Bend Mix	Sets amount of Bend voltage in Mixed Output
TFS Mix	Sets amount of TFS in Mixed Output
External Modulation	Sets amount of external modulation in Mixed Output
Offset	Sets positive or negative voltage offset of Mixed Output
Fine Offset	Fine adjust for offset of Mixed Output
Sample Level	Sets level of sample & hold input signal

Switch Controls (Toggle)

Switch	Function
Trigger Mode	Selects Between Normal/Hyper/Re-Trigger Modes
Gate Mode	Selects Between Ribbon/Ribbon Gated/Auto-Gating Modes
External/Ribbon	Selects Between Ribbon and External Input (S&H Mode)
S&H Mode	Selects Between Ribbon and Signal Generated Gating
V/I Mode	Selects Between Voltage and Current Controlled Modes

Indicators

Indicator	Function
Gate LED	Illuminates while gate is active
Trigger LED	Indicates Triggers (flashes once per trigger event)

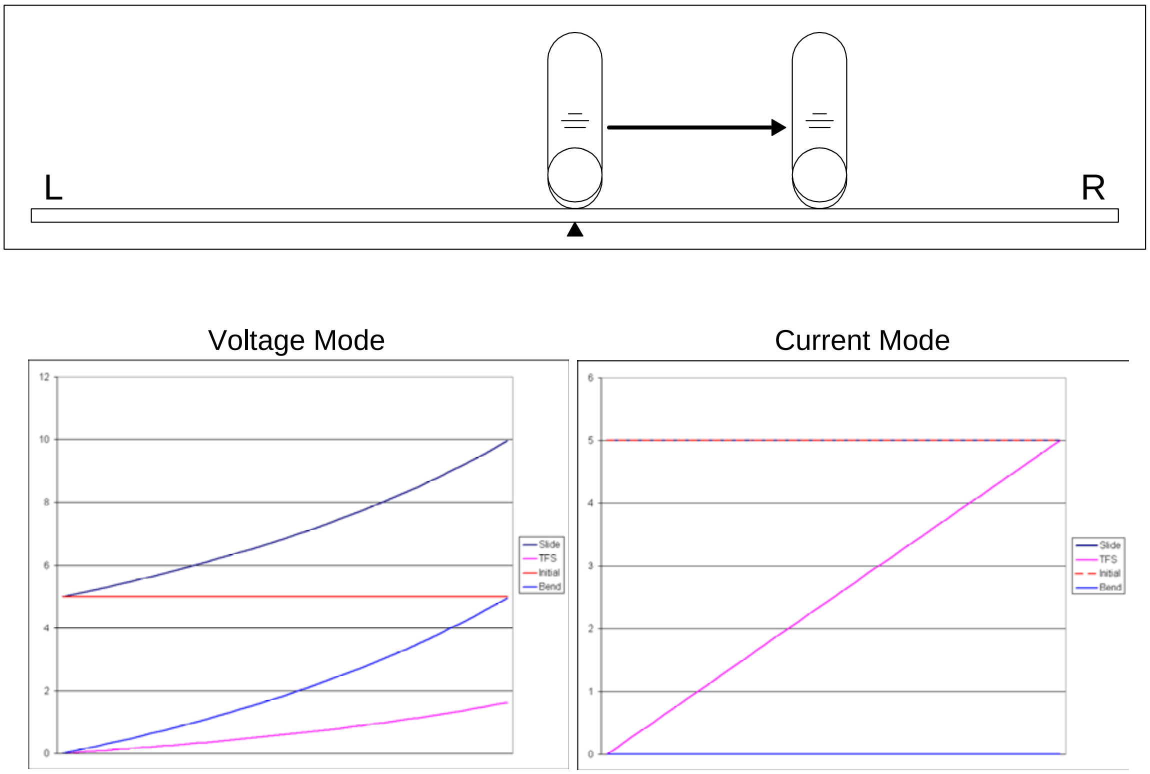


Figure 24: Two Point Pressure – Initial Middle, Second Sliding Up

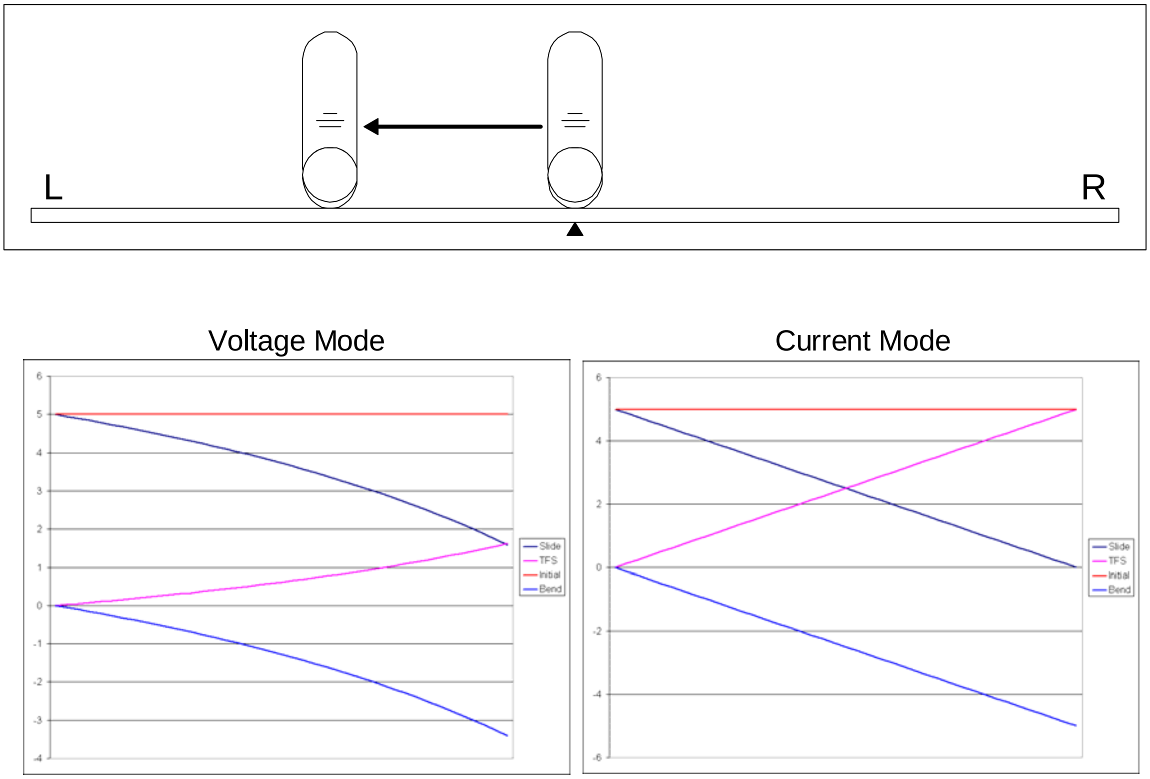
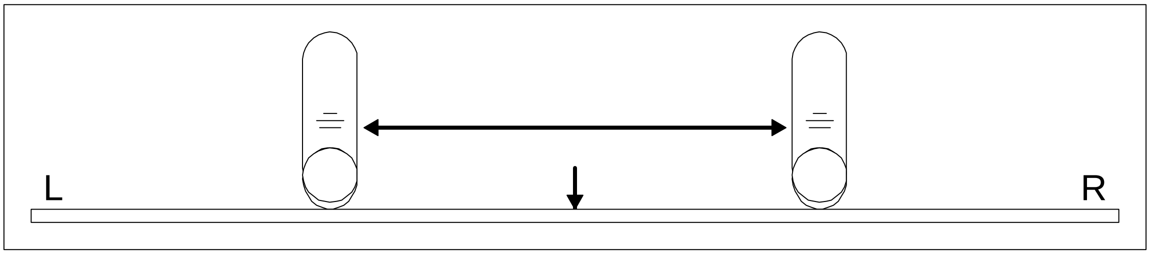


Figure 25: Two Point Pressure – Initial Middle, Second Sliding Down



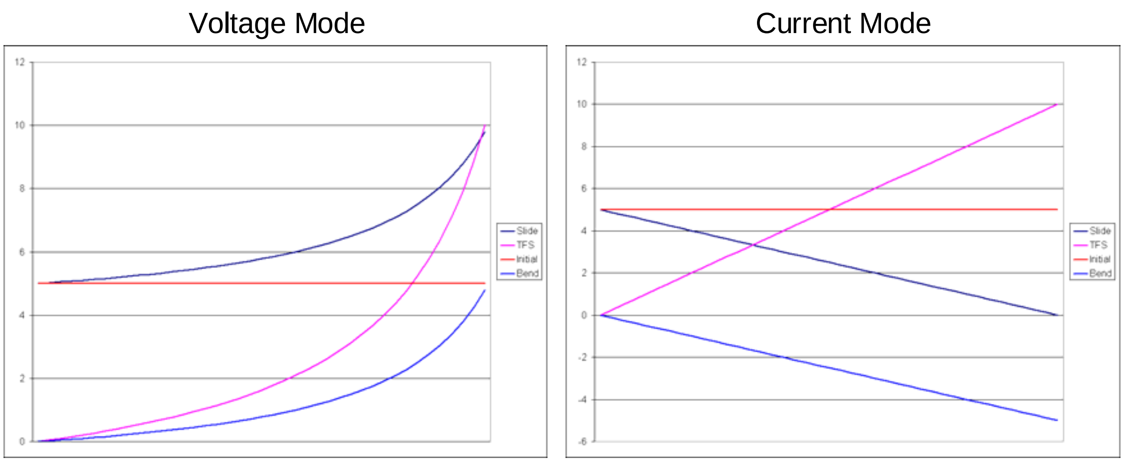


Figure 26: Two Point Pressure – Initial Middle, Spreading Down and Up Simultaneously